Rangeland classification system based on vegetative structure

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A RANGELAND CLASSIFICATION SYSTEM BASED ON VEGETATIVE STRUCTURE

by

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Understanding and predicting change in rangeland vegetation over time is a prerequisite to broad-scale ecosystem assessment. This analysis developed a new set of structural classes for use in characterizing rangeland vegetation for the Interior Columbia River Basin assessment.

The structural classes were developed through literature review and workshops held with ecologists throughout the Interior Columbia River Basin. These classes were then quantified using discriminate analysis techniques with a data set provided by the Forest Service. Data were put into cover type groups and then randomly divided into validation and analysis sets. A predictive discriminate function with the ability to accurately classify structural stages was developed using these data. The vegetation characteristics most influential in providing these classifications were also identified.

The results of this research provide a management tool in assessing rangeland vegetation change over time using vegetation characteristics that can be quantified and the ability to concentrate on those that are most influential for classification purposes.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

One of the objectives of the Columbia River Basin Ecosystem Management Project is broad-scale assessment of rangeland vegetation across the Columbia River Basin. The objectives of the Columbia River Basin project are to access current vegetation, both rangeland and forests, and to predict changes in that vegetation over time and under different management and/or disturbance scenarios. This work provides suggestions for management policies that may be implemented in the future within this ecosystem. My involvement is to characterize current rangeland vegetation within the region.

Landscapes can be defined as hierarchial mosaics of patches that differ in their age, size, shape, content and other aspects (Wu and Levin, 1994). The basis for rangeland landscape assessment is characterization of biophysical environments to describe interactions of climate, landform, soils and geomorphic processes. These characterizations provide a framework for testing key environmental and disturbance gradients that influence patterns and processes of biota. Landscape assessment also provides an understanding of factors that govern internal organization of ecosystems and their relationship to external variables such as disturbance events. The final step in landscape assessment is to evaluate a range of future outcomes, based on combinations of management strategies and variations in biophysical conditions and system dynamics. This range of future outcomes can be used by resource managers and the public to help identify management strategies that conserve ecological values and conditions to meet a desired goal (Scientific Integration Team, unpublished, 1994).

The objectives for my study were as follows:

1. To develop a procedure to classify rangeland vegetation based on the structure of the vegetation and to quantify this classification system using structural aspects;

2. To develop classification function equations useful in assigning vegetative plots (defined at various scales) to a vegetative structural class within a range cover type (Society of Range Management, 1994) based on plot data;

3. To develop a series of pathways to predict change in vegetation structure in response to various forms of disturbance, various management objectives and total protection;

4. To determine if key attributes in quantifying a structural class designation change over different scales.

Considering objective two, I am performing an assessment through a classification system at three scales; a macro-scale (regional level), meso-scale (occurring across a gradient of habitats or communities), and a micro-scale (individual communities of vegetation). The macro-scale is considered here because of the contract obligations of the Columbia River Basin Ecosystem Management Project and for recent and historical trends in management and ecological considerations at the broad-scale.

Ecologists have thought in terms of scale for quite some time. Watt (1947) stated that while the ultimate parts of the plant community are the individual plants, characterizing spatial relationships to each other at the individual plant level is impractical. In more recent years, Burke et al. (1991) stated that a shift of focus from site and site specific experiments to regions and regional analysis has been seen in management.

The Yellowstone National Park fires, for example, have challenged ecologists to extend their data and research to the scale of landscapes and the biosphere (Knight and Wallace, 1989). Knight and Wallace (1989) also stated that the spatial mosaic of Yellowstone National Park was a function of past disturbances superimposed on environmental gradients and that there are many uncertainties due to the complexity of interactions and the diverse mosaic at the large-scale.

It is at the regional scale that interactions and impacts of large-scale processes such as fire can be addressed and understood (Burke et al., 1991). Watt (1947) had also stated that many ecological processes occur at the ecosystem level, which is a somewhat elastic term that generally describes large geographic units. Romme and Despain (1989) suggested that the Yellowstone National Park fires have been occurring at a broad-scale and the mosaics of patchiness have changed at broad spatial and temporal scales since the early 1700's.

Abandonment of meso- and micro-scale assessments is not the intention of this study, but to develop a hierarchial system where information can be collected at the micro-scale, for example, and extrapolated to the broad-scale with ease incorporating the current trend of regional analysis. Ecodata plots in this study refer to 1/10 acre circular plots where a data collector accesses cover of shrubs, trees, herbaceous vegetation and other ecological attributes of the area (see Appendix A). This study is intended to extrapolate this micro-scale information into application at the broad-scale. Structural classes at the broad-scale are based mostly on the same ecodata fields that determine the micro-scale classifications.

Collins and Glenn (1990) used small-scale information and extrapolated it into regional level studies by using a core-satellite hypothesis to explain regional patterns of species distribution. They suggested that the patterns of grasslands studied on a local scale (meters squared) were similar to those of the regional-level distributions (kilometers squared). Factors effecting these distributions operated on both the small scale (competition and dispersal) and on the large scale (disturbances such as fire and overgrazing). Collins and Glenn (1990) further state that grassland community structure exhibits self-similarity in that the large-scale pattern is composed of numerous small scale patterns. They also suggest that small scale patterns are transposable to larger scale patterns and vise versa; however, the patterns are most obvious at an intermeadiate (community level) scale of analysis.

These reasons are why I feel that a system developed with a hierarchial structure based on the same attributes would be easy and accurately used. The ease and accuracy would come from the minimal changes in information when moving across scales and being able to join information from small scale studies and address broad-scale patterns and processes.

Study Area

The study area was located within the landscape characterization boundary for the Eastside and Interior Columbia River Basin Ecosystem Management Project (Figure 1). The landscape characterization boundary includes those lands in Washington and Oregon lying east of the crest of the Cascade Mountain

Range, including those in the continental United States within the Columbia River drainage in Forest Service Regions 1, 4 and 6, and portions of land administered by the Bureau of Land Management (BLM) in Oregon, Washington, Idaho and Montana (Scientific Integration Team, Unpublished, 1994).

The data analysis area included only those lands within the Region 1 boundary. This area encompasses portions of western Montana, north and central Idaho, and small portions of eastern Washington and Oregon (Figure 1). The shrub- and grass-dominated cover types of this region are most extensive in south-western Montana, in the wide intermountain valleys and extensive foothills, and in those areas east of the Continental Divide in Montana. Much of this area is characterized by nearly continuous mountain and gorge topography (Wambolt and Taylor, 1994). Shrub and grass cover types in these areas are thus limited in number and size.

The climate of the area is very diverse. In northern Idaho and northwestern Montana eastward to the Continental Divide in Glacier National Park, a moist inland maritime region exists that features a Pacific-coastal influence. In areas away from this maritime influence a colder, drier continental climate exists; with a decrease in elevation, warm, drier areas can be found composed of savanna, steppe, grassland and shrubland (Habeck, 1994).

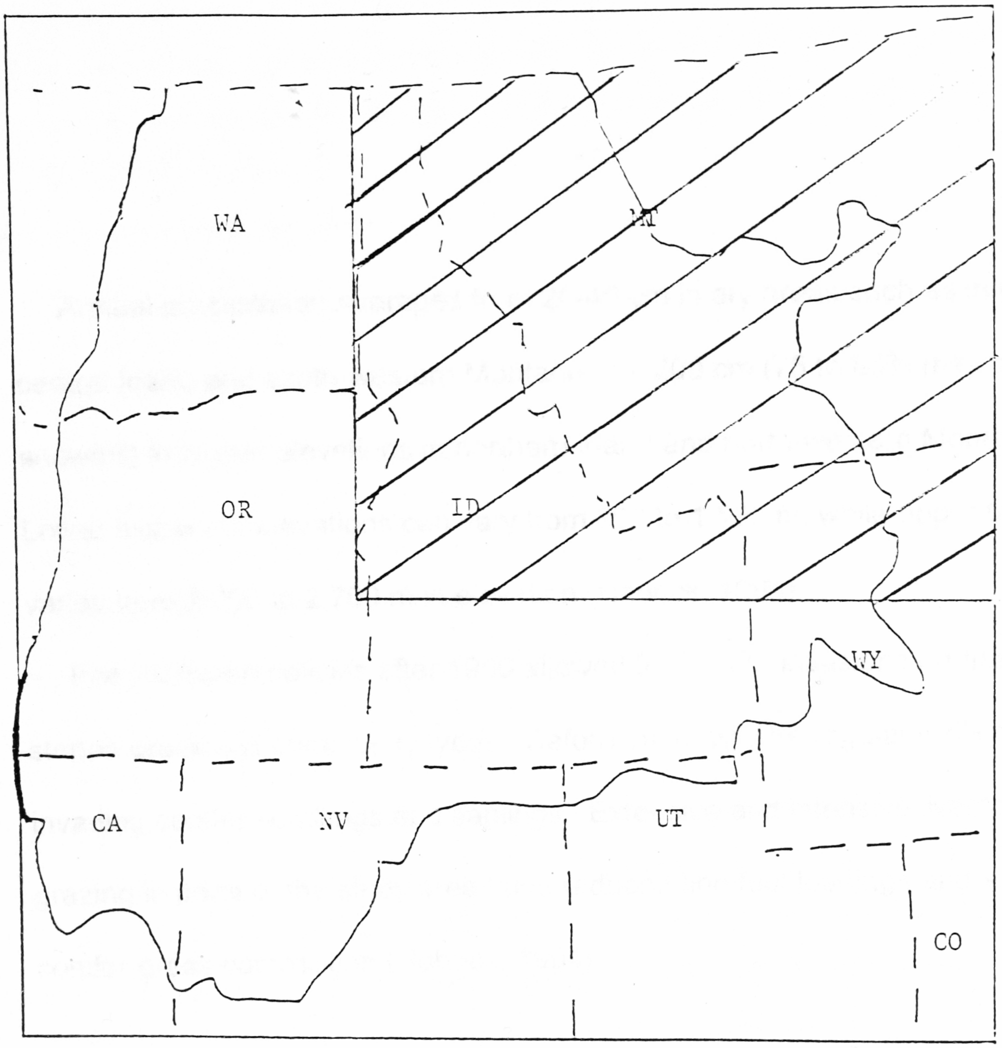
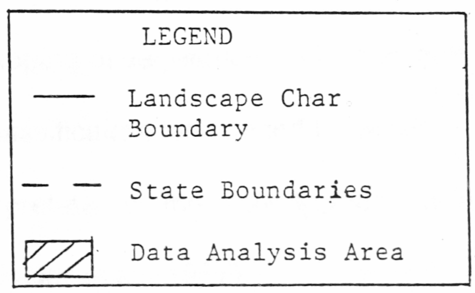


FIGURE 1. Map of Northwest Showing Study Area.



Annual precipitation averages from 20-40 cm in dry areas such as in east-central Idaho and south-western Montana, to 200 cm (75 to 85% may be snowfall) in higher elevations in northern Idaho and north-western Montana. Lower timberline elevations can vary from 800 to 1,500 m, while upper timberline varies from 2,000 to 2,700 m in elevation (Habeck, 1994).

Fire exclusion policies after 1900 allowed for conifer invasions on many steppe grassland community types. Before 1900, wildfire regularly killed invading conifer seedlings and saplings. Extensive and intensive livestock grazing in parts of the study area have reduced fine fuel loadings and altered conifer-grass competition (Habeck, 1994).

Literature Review

A basic goal of the scientific assessment of rangelands is the ability to use a vegetation classification that allows mapping of vegetation and projection of mapping units upon the landscape. Classification lends itself to better communication and management interpretations, and is the foundation for conducting and evaluating research (Pfister et al., 1977).

Presentation of a literature review comparing existing vegetation theory to the traditional climax vegetation theory is important at this point to show the underlying essence of this study. It is not the purpose of this study to criticize rangeland successional models based on climax theory but to develop an alternative or possibly a supplemental method for areas such as this study area that are process or disturbance driven. The literature has revealed the need to develop this system for application on these areas where the dynamics of the area is not realistically represented by traditional methods of classification.

There are three underlying premises for the development of my classification system: 1) the concern that climax or potential vegetation classification systems are inadequate as they stand alone to address process/disturbance driven areas; 2) the need to use existing vegetation to classify and develop pathway models in such areas; 3) the need to provide a supplemental system using structural attributes and changes to provide greater information.

<u>Examples of climax driven classifications.</u> Previous mapping of vegetation in the northwest has mostly involved separating somewhat homogeneous areas into habitat types or similar vegetation units as described by Hann (1989) and Wellner (1989). Pfister and Arno (1980) described habitat types based on potential climax vegetation. Habitat types can be defined as all land areas with

the potential capability of producing similar plant communities at climax, and are identified by the presence of indicator plant species (Pfister et al., 1977). Pfister et al. (1977) stated that transitional areas will not fit neatly into the habitat type classification. Habitat types assume directionality toward the dominance of a climax species over an area.

Community types (Alexander, 1988) and range sites (Leonard and Miles, 1989) have also been used as mapping criteria. Community types are closely related to habitat types in that both relate to a potential climax vegetation. Lee and Pfister (1974) defined a community type as a "designation for certain stands of questionable status." They suggest that further study is required to determine if they are truly "climax" or if they are persistent seral communities that will eventually be replaced.

Range sites also are used to classify vegetation. Range sites are similar to habitat types in that they attempt to classify vegetation based on the potential climax vegetation. The Society for Range Management (1974) defined range sites as:

> " A distinctive kind of rangeland, which in the absence of abnormal disturbance and physical site deterioration, has the potential to support a native plant community typified by an association of species different from that of their sites. The differentiation is based upon significant differences in kind or proportion of species, or total productivity."

An interpretive map based on range sites was produced by the United States Soil Conservation Service (1986).

Concerns with climax driven classification systems. While vegetation/site classifications have been used for several decades (Daubenmire and Daubenmire, 1968), the diversity of this study area develops a need for a classification system that uses existing vegetative characteristics.

Tisdale and Hironaka (1981) present an example of how the diversity of this study area and its disturbance driven nature develops this need. In recent years intensive studies on the sagebrush-grass region (parts of eastern Oregon and Washington, Utah, Nevada, southern Idaho, western Montana, northern California, Wyoming and Colorado) have led to the view that the region is ecologically stable with boundaries closely resembling those of pre-European settlement. Vale's (1975) review of his historical references also supports this view. Eggler (1941) also supported this view from his studies of sagebrush-grass vegetation on volcanic deposits in southern Idaho. Within the area of study in western Montana, however, on the tension zone between the sagebrush-grass and plains grasslands there is evidence of invasion of sagebrush due to fire succession (Tisdale and Hironaka, 1981, Morris et. al, 1976). This implies that perhaps using the notion of some idealistic "climax" vegetation in this area may be unrealistic where disturbance is a necessity in keeping out invading species.

A classification of climax communities (habitat types or range sites) may provide a reference base, but is of limited value by itself because relatively few examples of climax states remain in most sagebrush communities in this area. What is needed is a classification system of disturbed communities associated with each habitat type for maximum utility (Tisdale and Hironaka, 1981).

Practically all rangeland classification systems presently in use are based on climax or potential vegetation (Society for Range Management, 1994). These classification systems use Clemetisian ideas of plant ecology in terms of vegetation change in an area. This vegetation change has directionality assumed in it as an area approaches a "climax" plant association which is then assumed to be stable (Westoby et al., 1989). A "stable climax" ecosystem is a questionable concept especially when one is in an area as diverse and disturbance driven as this study area. Classification systems that follow the potential vegetation/climax school of thought consider disturbances as anomalies in the natural process of succession toward a climax plant association (Laycock, 1991). The opposite is the case for this study area where disturbances are frequent and achieving a "stable climax" plant association for a prolonged period of time is rare.

The fact that succession to a "climax" state can be halted at some stable state also questions the reality of the climax theory (Laycock, 1991). These stable states may rely on disturbance to be forced into a transitional phase. Allen (1989) discussed the influence of rate and pattern of succession and also that some different trajectories of succession may not allow a disturbance driven ecosystem to return to a climax state. Laycock (1991) stated that in order to effectively manage our rangeland resources, we need to go beyond conventional wisdom of climax ideas in the range management profession.

Changes in vegetation structural attributes over time are best addressed by what is called a "state-and-transition" model (Westoby et al. 1989). Westoby et al. (1989) proposed that successional patterns on rangelands follow what is called a "state-and-transition" model as opposed to the rangeland successional models induced by Clementisian ideas of plant ecology. While Clementisian models have directionality implied within them, state-and-transition models do not (Westoby et al., 1989). Change or "transition" from one "state" to the next is triggered by disturbances, natural or otherwise. States can be identified as recognizable and sometimes relatively stable assemblages of vegetation or vegetative structure on a landscape. Under the state and transition model, range management would not see itself as establishing a permanent equilibrium. Rather, it would see itself as engaged in a "continuing game" of ever changing areas due to disturbance where management emphasis would be placed on timing and flexibility rather than and establishing a fixed policy.

Federal legislation over the past two decades has intensified the need for standard cover type descriptions for the inventory of existing rangeland vegetation (Society for Range Management, 1994). Rangeland cover types use the distinguishing characteristics of existing vegetation as a classification system and address the reality of vegetation development on rangelands. Using these cover types as a baseline my developed classification system should be able to be incorporated with other systems in areas where potential vegetation or climax classification systems are not realistic. This study and its methodology were developed with the state and transition model concept in mind as reviewed in Westoby et. al (1989) and Laycock (1991) using existing vegetation.

Increased use of remote sensing technology dictates the need for a vegetation classification scheme that allows interpretation of remotely-sensed data using minimal assumptions. Remote sensing techniques do not address potential vegetation classifications without assumptions as readily as they would with an existing vegetation classification system. Classification based on existing vegetation would lend itself to easier interpretation from this technology. My study incorporates the inventorying of existing vegetation variability across a landscape as in rangeland cover types. Structural attributes and structural change within these rangeland cover types are the focus of this study.

Vegetative structure on rangelands generally includes such attributes as openness, clumpiness, crown differentiation (shrubland types), canopy coverage and other general attributes of both vertical and horizontal structure. Literature on rangeland structural classification is sparse. For the Columbia River Basin (CRB) Ecosystem Management Project an approach to vegetation classification using structure was chosen because of the natural linkages between structure and resource values (For example, what grazing practices can be implemented on areas with certain structures). The CRB project chose a structural approach as a directive to be able to incorporate disturbance into vegetation projections with flexibility and for the potential to use remote sensing of existing stand structures (O'Hara et. al, unpublished, 1995). The above reasons from the CRB project and the additional reasons that follow are why structural attributes were chosen as the "backbone" of this classification system and why, for my study, I expanded the system using structural attributes as a classification tool.

Oliver (1981) used stand structure to describe the process of stand development in forests. Oliver's approach was further developed for western redcedar (*Thuja plicata* Donn.) stands in northwest Montana and quantified in McNicoll (1994).

McNicoll (1994) stated that:

> ...This approach (Oliver's) can provide a framework for qualitative assessments of temporal and spatial changes in vegetation patterns across the landscape. The primary components of this framework include: 1) the competitive interactions among individual members of a stand for occupancy of growing space over time, and 2) the intensity and frequency of autogenic and allogenic disturbances that release previously occupied growing space....

Similar logic has potential for application to rangeland vegetation classification. Initial structure of a grassland or shrubland is critical in determining its transition to another state. For example, a natural grassland with closed canopy structure resists shrub invasion (Tisdale and Hironaka, 1981). Other ecosystem processes such as nutrient cycling, movement of plant and animal species, and fire are affected by structural attributes on the landscape (McNicoll, 1994).

The classification system based on structure will provide additional information to the existing classification schemes. Several processes on rangelands are effected by structure and thus give importance and worth to this approach using existing structure to classify rangelands. For example, McAuliffe (1988), studied the structural effects of a shrubland community in Arizona. He found that structure (canopy cover and density) of *Ambrosia* spp. affected the recruitment of *Larrea* spp., where 85.5% of all young *Larrea* spp. rooted beneath the canopies of the *Ambrosia* spp. This is an example of how structure effects small scale processes such as recruitment in rangelands.

Wildlife are also affected by structure on rangelands. For example, Sage grouse (*Centrocercus urophasianus*) and Columbia ground squirrels (*Citellus columbianus)* are two examples of wildlife affected by structural attributes. Martin (1970) studied the effects of spraying big sagebrush (*Artemisia tridentata*) on sage grouse habitat and found that the occupancy of sage grouse on sprayed sites (reduced sagebrush cover) was 4% of the total, whereas the unsprayed sites (more sagebrush cover) accounted for 96% of the occurrences. Connelly et al. (1988) found that sage grouse have quickly taken advantage of newly disturbed areas and that sage grouse leks can be relocated using man-made clearings (changes in structure) where sagebrush cover is near. This species acceptance of newly cleared sites for display areas illustrates where knowledge of vegetation structure can be used in management.

Columbia ground squirrel populations tend to increase as excessive domestic sheep grazing causes plant community retrogression on grasslands in central Idaho (Lambeth and Hironaka 1982). Excessive sheep grazing changes the grassland structure from mid-grasses to short vertical structure preferred by Columbia ground squirrels, which rely on short vertical structure to see ground predators.

Water yield is another ecological process affected by vegetation structure. A closed grassland canopy allows more soil moisture to enter an aquifer than does a canopy of shrubs, providing for more water in streams via below ground flow (Kimmis, 1987). Kimmis (1987) stated that stream flow can be increased by the reduction of interception and transpiration. Shrubs can act as "pumps" transpiring water back into the atmosphere. Changes in structure may affect the timing of the hydrological cycle in terms of snow melt.

Fuel loading and fire potential are also influenced by vegetation structure across a landscape. A grassland with closed canopy structure has a greater fire potential than an open canopy structure (Tisdale and Hironaka, 1981). Land managers can map and predict fire potentials using a structural classification system. Presence of ladder fuels within a woodland or tall shrub type can be predicted by structural classification as they enhance the ability to carry a ground fire into the tree or shrub canopy on prescribed burns or wild fires.

Grazing management is also affected by structure. Grazing of shrub-like structures will best be done by goats, whereas grassland structures are more suited for cattle. Where a grassland structure is desirable and a shrub-like structure is present, it is possible to use goats to initiate this change in structure (Vallentine, 1989). Livestock grazing can be used as a tool to modify vegetation structure having a high fire potential.

Another objective of my study was to develop conceptual models or pathways using the new classes developed from the study. These pathway models will be presented as hypotheses only and will require future study. Rates and potentials for transitions from one class to the next would be useful for predictive purposes (Calloway and Davis, 1993). The underlying premises for the development of the pathway models in this study go hand in hand with the concerns of climax driven classifications reviewed earlier. A key transition made largely during the 1970's was the gradual de-emphasis of the classical models of ecology that assume the existence of equilibrium points (DeAngeles, 1987). DeAngeles (1987) suggested that instabilities caused by non-linear feedbacks and time-lags in the interactions of biological species and stochastic forces have revealed the need to build stability into models where stochasticity can be accounted for. DeAngeles (1987) further suggested that disturbance pathways that have adverse feedback effects from disturbance can be stabilized by integrating small-scale systems into large landscapes, and that this may be one way to deal with the instabilities of past models.

The pathway models I have developed for this study take into account disturbances as a driving force of the model, much in the same way as the state-and-transition models reviewed in Westoby et al. (1989). A practical difficulty of past models based on a target equilibrium state is that they can not be extrapolated down to smaller scales on which observations are often made (DeAngeles, 1987).

My pathway models are developed with a hierarchial set up and data collected at the level of the ecodata plots is applicable in the classification and transition of broad-scale plots which use the ecodata variables. Models set up in a hierarchial structure provide a context for studies at specific sites and, second a scheme for formulating general and testable hypotheses (Pickett et al., 1987) Picket et al. (1987) concluded that models that were not based on some type of hierarchial structure do not lend themselves to the formulation of general and testable hypotheses.

Connel and Slayter models as reviewed by Pickett et al. (1987) use successional patterns and species replacement in a more or less strict sense for the mechanisms of their pathway models and need to make exceptions for disturbance events. These models are based almost entirely on temporal aspects (Pickett et al. 1987). It is my opinion is that disturbance in my study area is not tied down to only temporal aspects or rates of succession. Another problem with successional models such as Connel and Slayter is that successional models have shown, although there is much information available on patterns of succession, that there is currently no general theory to organize this information and to relate patterns and mechanisms (Pickett et al., 1987).

Markovian dynamic models have been used by McAuliffe (1988) and use circular dynamic pathways for relationships between openings and presence of shrubs and understory. Markovian chains provide a stochastic model in which the transitions among states occur with probabilities that depend only on the current state (McAuliffe, 1988). McAuliffe (1988) described two types of chains; 1) a homogeneous chain where constant probabilities and rates over time are used; and 2) non-homogenous chains where probabilities and rates are not constant over time.

It is my opinion that homogeneous Markovian chains would not address this classification system in terms of developing pathway models due to the establishment of constant probabilities and rates in a disturbance area. Non-homogeneous Markovian chains may be a viable option where rates and probabilities could be adjusted on the basis of a recent disturbance. As stated before, the pathway diagrams presented in this report are presented as hypotheses and develop the need for further research.

In order to develop new concepts and models about range condition, we not only need to identify possible states, we also need to identify and understand the factors which can force a community across a threshold into a transitional phase moving toward another state. How the existing vegetation types react to disturbance is basic knowledge that a researcher needs in order to develop these new models and concepts. The literature review encompasses only those cover types that were used in the analysis and for which pathway diagrams were developed.

Tisdale (1994a) reported that grasses comprise 80-90% of the total production at or near climax in the Bluebunch Wheatgrass cover type in the northwest. (Tisdale, 1994a). Fire is a less important disturbance element in this cover type, as bluebunch wheatgrass (*Agropyron spicatum*) is fairly tolerant of fire. Damage can occur, however, from fires under very hot, dry conditions (Tisdale, 1994a). Fire can maintain this type of community by excluding non-sprouting shrubs (Vallentine, 1989)

Bluebunch wheatgrass is shown to be a decreaser under heavy grazing and also is commonly the most selected species of the cover type when grazed (Mueggler and Stewart, 1980). Herbage production of bluebunch wheatgrass is severely reduced by even one year of clipping and repetition for 2 or 3 consecutive years kills most plants. Recovery of bluebunch wheatgrass requires up to 6 years to regain normal vigor (Tisdale and Hironaka, 1981). *Artemisia tridentata* and *Chrysothamus* spp., normally incidental shrubs on good condition range of this type, may increase to a level of dominance under extreme overgrazing (Mueggler and Stewart, 1980). Burning of sagebrush-grass stands in this cover type may reduce the yield of the grasses the first year but yields should increase by the third year (Tisdale and Hironaka, 1981).

McLean and Tisdale (1972) estimated from their study that it takes 20-40 years for overgrazed grasses such as bluebunch wheatgrass to recover to excellent condition. Little change took place inside their enclosures placed on poor condition range in less than 10 years following fencing. It took longer for poor ranges to progress to fair condition than for fair ranges to progress to good condition.

Idaho fescue (*Festuca idahoensis*) is the diagnostic species in the Idaho Fescue / Bluebunch Wheatgrass cover type with bluebunch wheatgrass always present as a clear codominant. Idaho fescue and bluebunch wheatgrass are the principle species that decrease with heavy grazing in this cover type. In some cases, Idaho fescue may increase with the reduction of bluebunch wheatgrass, but it will eventually decrease with continued heavy grazing, giving way to a minor shrub component and/or lower successional herbs (Taylor, 1994a). Clipping experiments show that Idaho fescue of moderately low vigor requires about 3 years to regain full vigor while bluebunch wheatgrass of low vigor can take more than 6 years to recover (Mueggler, 1975).

Idaho fescue is less tolerant of fire than many grasses including bluebunch wheatgrass. In some cases yields of fescue do not fully recover until 12 to 15 years after a burn due to injury of plants and competition from other herbaceous species that could increase 2 to 3 years after burning (Tisdale and Hironaka, 1981).

Idaho fescue in the Idaho Fescue / Slender Wheatgrass cover type responds to disturbance in the same way as described in the Idaho Fescue / Bluebunch Wheatgrass cover type. Idaho fescue is the dominate grass in this cover type with slender wheatgrass (*Agropyron trachycaulum*) consistently present. With heavy overgrazing, the dominant grasses tend to be replaced by less palatable and less productive species. Several sedges act as grazing increasers and mountain big sagebrush (*Artemisia tridentata*) may become abundant with continued overgrazing (Taylor, 1994b).

Considering the study area encompassed by this study, the Mountain Big Sagebrush cover type was addressed as a disturbance or invasional cover type into a grassland. Mountain big sagebrush grows in areas of higher moisture and lower temperatures than other subspecies of *Artemisia tridentata* (Tisdale and Hironaka, 1981). This disturbance type is marked by the dominance of mountain big sagebrush and a more or less well developed understory of grasses and forbs. The cover type reacts to heavy grazing by a marked decrease in palatable forbs and grasses, while the sagebrush (relatively low in palatability), becomes more dense and vigorous. Depleted stands typically consist of dense shrub cover and an understory dominated by less palatable forbs and grasses (Tisdale, 1994b). Widespread invasion of exotics is seldom characteristic of depleted conditions, but reduction in density of bunchgrasses and exposure of bare ground is common (Hironaka et al., 1983).

The necessity to control sagebrush is paramount for rangeland improvement either to release desirable understory species or in preparation for seeding. Many brush control methods have been developed including mechanical, chemical and prescribed burning (Lanchaster et al., 1987). Mountain big sagebrush is easily killed by fire, but can reestablish itself where large seed banks are present (Tisdale, 1994b). Without management action, mountain big sagebrush can commonly live 40 to 50 years with some plants exceeding 100 years (Tisdale and Hironaka, 1981).

Anderson and Holte (1981) discovered in a 25 year exclosure study that 25 years of absence from grazing by livestock caused the cover of shrubs and perennial grasses to nearly double. They also drew the conclusion that, in absence of a major disturbance such as fire, the grasses would reach some sort of equilibrium and would not be able to overtake the shrub component.

The Chokecherry / Serviceberry / Rose cover type is a combination type consisting of many shrubs and a variety of grasses. The main components are: chokecherry (*Prunis virginiana*), serviceberry (*Amelanchier alanifolia*), wild rose

(*Rosa* spp.), and snowberry (*Symphoricarpos* spp). This cover type consists of many overstory and understory species and much is left to be learned about the ecology of this type (Winward, 1994).

Serviceberry reaches heights of 1 to 2 meters depending on site quality and grazing pressure. Ages of 50 to 85 years are attained where the plant is climax. The aerial portions of serviceberry are easily destroyed by fire, but survival usually occurs through root sprouting. Light grazing stimulates growth, and full vigor can be maintained under a use rate of 60% in fall or winter (Tisdale and Hironaka, 1981).

Riggs and Urness (1989) studied the response of serviceberry and snowberry to intense goat grazing over a period of three years. Productivity and sprout vigor was reduced in the serviceberry. The snowberry also had a reduction in productivity due to the goat browsing.

Chokecherry is seldomly browsed by domestic livestock because technically, the plants are toxic throughout the summer and spring, but animals rarely eat enough to be affected (Tisdale and Hironaka, 1981). It readily sprouts after clipping or burning. Schier (1983) found that chokecherry was vegetatively propagated from cuttings of rhizomes and arose singly or in clusters from suppressed buds. Shoots emerged from the media in as little as 19 days. Chokecherry can reach heights of 4 to 5 meters tall.

The woods rose, an example of the *Rosa* genera, is a prostrate to upright shrub from 0.5 to 3.0 meters tall and is browsed in all seasons by livestock and big game. Some ecotypes of woods rose spread aggressively by root sprouting (Blauer et al., 1975).

The Wheatgrass / Needlegrass cover type is fundamentally a perennial mixed grass prairie in which the mid-grass component (wheatgrasses and needlegrasses) maintains dominance over the short grass component (mainly blue gramma and sedges) throughout most of the range of this type (Whitman and Baker, 1994). Because so many species are included in this cover type the main grass species will be presented. Western wheatgrass (*Agropyron smithii*) will be focused on as the mid-grass component and blue gramma (*Bouteloua gracilis*) will be focused on as the short grass component in this overview.

With heavy grazing, western wheatgrass is a definite decreaser and blue gramma is an increaser (Mueggler and Stewart, 1980). Olson et al. (1993) confirmed this observation stating that under intensive stocking of steers, western wheatgrass performed as a decreaser and that shifts from cool- to warm-season grasses can be expected with extreme early use. Recovery is usually slow on sites where it has been depleted. Reaction to 2 years of spring use of 50% utilization usually will include a 21% reduction in leaf length (Hart et al., 1993).

Differences in soil moisture in pre- and post-burn conditions can cause different results of forage production on burned sites, wet conditions usually stimulate more forage productivity than dry sites. White and Currie (1983) saw that when soil moisture was not limiting, higher production was seen for western wheatgrass after burning and where soil moisture was limiting the production of blue gramma on these sites was the greater of the two.

The Columbia River Basin Ecosystem Assessment Project is more directed toward developing a methodology for future research and improvements than focusing only on the results. This study should be viewed as a research and development study, creating the potential for new research focused on using and improving these methods.

METHODS

Structural Classification

Three sets of structural classes were developed, each at a different scale. Structural classes at the macro-scale were developed for use by the Columbia River Basin Ecosystem Management Project. The other sets of structural classes for the meso- and macro-scale were developed for purposes of this study alone. No analysis was done on the micro-scale classification system. This set of structural classes is presented as a suggestion for future expansion of this system. Method development was the main goal of this study. Stages and pathways of structural change were developed through a literature review.

Macro-scale classification. The macro-scale set was developed to classify vegetation at 1 km pixel resolution across the study area. The initial classification was to be quantified using discriminate analysis on data collected in ecodata plots. Only Region One data were available so the classification is quantified for this area only. An extensive literature review of the Society for Range Management (SRM) cover types within the assessment area was conducted to gain an understanding of the state of knowledge relative to possible structural classes at the macro-scale. The SRM cover types for this scale are shown in Table 1.

Table 1. Grassland and Shrubland Cover Types for the Columbia River Basin

Grasslands

SRM 101 - BLUEBUNCH WHEATGRASS

SRM 103 - GREEN FESCUE

SRM 304 - IDAHO FESCUE / BLUEBUNCH WHEATGRASS

SRM 306 - IDAHO FESCUE / SLENDER WHEATGRASS

SRM 607 - WHEATGRASS / NEEDLEGRASS

SRM 614 - CRESTED WHEATGRASS

Shrublands

SRM 104 - ANTELOPE BITTERBRUSH / BLUEBUNCH WHEATGRASS

SRM 206 - CHAMISE CHAPARRAL

SRM 208 - CEANOTHOUS MIXED CHAPARRAL

SRM 401 - BASIN BIGBRUSH

SRM 402 - MOUNTAIN BIG SAGEBRUSH

SRM 403 - WYOMING BIG SAGEBRUSH

SRM 406 - LOW SAGE

SRM 414 - SALT DESERT SHRUB

SRM 421 - CHOKECHERRY / SERVICEBERRY / ROSE

Workshops under the direction of the Forest Service were held with 30-40 resource specialists from throughout the study area to help develop a classification system. The macro-scale structural classes developed were used to label a raster layer and to evolve the predictive functions across the Columbia River Basin (CRB). The number of structural classes was restricted to seven because of restrictions of the computer model into which these were incorporated.

Meso- and Micro-Scale Classifications

Further literature review was done to expand the classification system into one that would be useful for application at meso- and micro-scales. The same SRM cover types were used as a basis for developing these sets of structural classes. The meso- and macro-scale classes were also set up from a hierarchial viewpoint so that management adjustments from one scale to the next would be possible. Discriminate analysis was performed on the meso-scale classification but not on the micro-scale classification.

Discriminate Analysis Review

The overall goal of developing these classification systems was for descriptive and predictive purposes. The macro- and meso-scale classes were quantified using discriminate analysis so that distinct "mutually exclusive" groups could be recognized using attribute values contained in Forest Service ecodata plots. The ecodata plots in this study refer to 1/10 - acre circular plots where a data collector accesses cover of shrubs, trees, herbaceous vegetation and other ecological attributes of the area (see Appendix A). Discriminate analysis allowed the determination of whether the initial classification could be quantified with reasonable accuracy, and if vegetation across a region could be accurately classified with variables within an ecodata database.

Discriminate analysis is a statistical technique which allows simultaneous study of the differences between two or more groups with respect to several variables. By analyzing differences between classes and provides a means to assign any case into the class which it most closely resembles. The basic prerequisites of discriminate analysis are that two or more groups (classes) exist, they differ on several variables and that discriminating variables can be measured at the interval or ratio level (Klecka, 1980). This study used structural classes as the distinct groups and ecodata attributes as the measurable variables. A researcher is engaged in "interpretation" when studying the ways in which groups differ; i.e., one is able to "discriminate" between the classes on the basis of some set of characteristics, to determine how well they discriminate and to determine which characteristics are the most powerful discriminators (Klecka, 1980).

Data Set Development

Several data files were provided by Region One of the Forest Service. Raw data were presented in four sets: "east, west, lolo and tree", in a comma delimited format. After setting up data structures in the Fox-Pro database software, the data were converted and imported into these data structures for handling and preparation for discriminate analysis using the SYSTAT software DISCRIM program (Wilkinson, 1989). Data were further divided into forest and range data sets. The ecodata files were in the general form format and contained numerous fields (see Appendix A). Records with 5% or more total tree cover were transferred to the forest data base.

During data set standardization, erroneous records were deleted. This was mostly accomplished using Fox-Pro commands and queries and by visually inspecting records. Any record that had total tree cover greater than the tree cover elements (total seedling cover + total sapling cover + total pole cover + total medium sized tree cover + total large tree cover + total very large tree cover + 5), or total tree cover was less than zero, was taken out of the usable files for the analysis. The call standards for ecodata plots are plus or minus one cover class and for this study it was decided that the standards should be one-half a cover class which correlates to the plus five. If total tree cover was less than zero, most likely the value was -1 which indicates that the tree cover was not accessed in that area. The same procedure was performed on the shrub cover fields (total shurb cover > (total low shrub cover + total medium shrub cover + total tall shrub cover + 5) or total shrub cover was < 0) and the records were placed in the appropriate files.

Records that had "SI" or stand initiation in the stage (STAG) field were transferred to the forest records. An "SI" recorded in the STAG field meant that this plot was expected to progress into a forest type and not to a grassland or shrubland type. Records that had zero percent total tree cover were checked to see that none of the tree cover elements had any value other than zero in them. If they did then the records were moved out of the usable data set. The same operation was used on the shrub cover fields as stated above.

Any record that had a value of -1 in the tree cover fields or the shrub cover fields was removed from the analysis because a value of -1 in these fields indicates that the accessors did not access this cover field and, since these fields would be used in the analysis, true values would be needed. The same procedure was performed on the grass cover (GRAM) and forb cover (FORB) fields, removing any record that had a value of -1 from the usable records. Files from the forest data base, debugged in the above manner, that appeared to be range types, were transferred to the range data base. These files were inspected and merged into the appropriate usable files.

After these procedures, due to the small number of usable records, several records were "salvaged" from files that contained tree cover fields and shrub cover fields that had values of -1. Any record from this file that contained a -1 in TCOVTOT (total tree cover) or SCOVTOT (total shrub cover) was not retrieved to be used in the analysis. Salvage of the other records in this "bad" file operated under certain assumptions. Tree cover data fields may not have been filled in because there was no tree cover in the area. The total tree cover may have been zero and the other cover fields may have been left blank, thus the cover value of -1. For this analysis The -1's in these fields were changed to zero only if after doing so the total of all the tree cover fields added exactly to the total tree cover. These assumptions were also applied to the shrub cover fields. Salvaged records were then "filtered" through the cover type assignments and placed into appropriate cover type files. Once the data were "debugged" and a set of usable data records were obtained, the east, west, Lolo and tree data records were merged into one file. Only the fields to be used in the analysis were retained and all others were dropped from the data set for simplicity. The remaining General Format fields are identified by an asterisk in Appendix A.

Two fields were then added to the data base structure to include a cover type field (COVTYPE) and a field to hold the structural class or stage identification (STAG). COVTYPE holds a code for that record which correlates to the appropriate SRM rangeland cover type.

Records were first divided into SRM rangeland cover types files. Then, within each cover type, these records were assigned to the appropriate structural class or stage since different cover types had different potential structural classes. Next the data set was divided into potential shrub cover types and herbland cover types by including records that had $\geq$ 10 percent total shrub cover in a shrub database and the remaining records (<10 total shrub cover) would become the herbland database.

Herbland Cover Type Assignment

Individual records of the herbland database were identified and copied to the appropriate SRM cover type file using Fox-Pro commands and performing manual searches afterwards.

Cover Type Assignments using Fox-Pro Commands. The separation of records was done by querying the CTDOML (dominate lower vegetation layer and CTCODL (codominate lower vegetation layer) fields to determine the existing vegetation and then placing that record into a SRM cover type file. This was done using Fox-Pro commands. Table 2 shows a summary of the criteria used in determining a records cover type.

Not enough records in the data set (in either the automated or manual search) contained "FESVIR" *(Festuca viridula)* in the CTDOML field to assign to a SRM 103 (Green Fescue) cover type. This cover type was dropped from the analysis.

A search of the records revealed several records having "FESSCA" *(Festuca scabrella)* within the CTDOML and CTCODL fields. These records justified the inclusion of an SRM 312 (Rough Fescue / Idaho Fescue) cover type. After all of the other cover types had been assigned, any record that had "FESSCA" in the CTDOML or CTCODL fields was assigned to this cover type using the manual assignment methods described in the following section. Records for the SRM 607 (Wheatgrass / Needlegrass) cover type were assigned through manual cover type assignment techniques described in the following section.

<u>Manual Cover Type Assignments.</u> Manual searches were performed through the rest of the data records to assign them to appropriate SRM rangeland cover types. This was done by browsing the records one by one for potential assignments and manually labeling and removing each record.

Table 2. Assignments of herbland records to SRM cover types based on existing vegetation.

DOMINATE EXISTING VEGETATION	CODOMINATE EXISTING VEGETATION	COVER TYPE ASSIGNMENT FOR THAT RECORD
AGRSPI (*Agropyron spicatum)*	ANY	SRM 101 - BLUEBUNCH WHEATGRASS
FESVIR (*Festuca virdula)*	ANY	SRM 103 - GREEN FESCUE
FESIDA (*Festuca idahoensis)*	AGRSPI (*Agropyron spicatum)*	SRM 304 - IDAHO FESCUE / BLUEBUNCH WHEATGRASS
FESIDA *(Festuca idahoensis)*	AGRCAN (*Agropyron trachycaulum)*	SRM 306 - IDAHO FESCUE / SLENDER WHEATGRASS
AGRCRI *(Agropyron cristatum)* or AGRDES *(Agropyron desertorum)*	AGRCRI *(Agropyron cristatum)* or AGRDES *(Agropyron desertorum)*	SRM 614 - CRESTED WHEATGRASS

Table 3. Manual cover type assignments for the herbland records.

SPECIES PRESENT	ELEVATION RANGE	COVER TYPE ASSIGNMENT FOR THAT RECORD
AGRSPI *(Agropyron spicatum)*	3,000 to 6,000 ft.	SRM 101 - BLUEBUNCH WHEATGRASS
FESIDA *(Festuca idahoensis)*	< 5,000 ft.*	SRM 304 - IDAHO FESCUE / BLUEBUNCH WHEATGRASS
FESIDA *(Festuca idahoensis)*	> 6,500 ft.*	SRM 306 - IDAHO FESCUE / SLENDER WHEATGRASS
FESSCA *(Festuca scabrella)*	< 7,000 ft.	SRM 312 - ROUGH FESCUE / IDAHO FESCUE
AGRCRI *(Agropyron cristatum)* or AGRDES *(Agropyron desertorum)*	ANY	SRM 614 - CRESTED WHEATGRASS

* Elevations from 5,000 to 6,500 ft. with FESIDA present were considered overlapping areas for the SRM 304 and SRM 306 cover types and were not identified as either.

This encompassed looking for a rangeland cover type species and determining that no other cover type identification was possible and further backing this assignment with elevation distinctions. Most of the elevational information for these decision rules came from Mueggler and Stewart (1980) or the rangeland cover type book (Society for Range Management, 1994). Table 3 shows the criteria in a summarized form for these manual cover type assignments.

The SRM 607 cover type was basically used for all of the wheatgrasses and needlegrasses not identified by the other SRM cover types above. Records were assigned to this cover type if AGRSMI (*Agropyron smithii)*, AGRDAS (*Agropyron dasystachyum)*, STICOM (*Stipa comata),* STIVIR (*Stipa viridula),* BOUGRA (*Bouteloua gracilis),* POASAN (*Poa sandbergii)* or other *Poa* species were present in combination in the CTDOML and CTCODL fields, and the elevation was from 1,500 to 4,000 ft.

Shrubland Cover Type Assignment

Assignment of records to SRM shrubland cover types was done in a manner similar to that of the herbland data base. The records were identified and assigned using the following criteria and then copied into separate files.

Cover Type Assignments Using Fox-Pro Commands. The same approach was taken for the shrubland records for assigning records to a cover type. Existing vegetation was assessed in the CTDOMM (dominant mid-layer vegetation) and CTCODM (codominate mid-layer) fields and assigned to the appropriate cover type by using Fox-Pro commands and are summarized in Table 4.

Manual techniques described in the following section were used to place plot records into their appropriate cover type for several of the shrubland cover types. These cover types were SRM 206 (Chamise Chaparral), SRM 208 (Ceanothus Mixed Chaparral), and SRM 421 (Chokecherry / Serviceberry / Rose).

In the Region One data set it was apparent that no salt-desert shrub records would be found and the cover type SRM 414 (Salt-Desert Shrub) was dropped from the analysis.

Manual Cover Type Assignments. Shrubland type records remaining after using Fox-Pro assignments were browsed and put into appropriate cover type files based on the following criteria described in Table 5.

Table 4. Assignment of shrubland records to SRM cover types based on existing vegetation.

DOMINATE EXISTING VEGETATION	CODOMINATE EXISTING VEGETATION	COVER TYPE ASSIGNMENT FOR THAT RECORD
PURTRI *(Purshia tridentata)*	ANY	SRM 104 - ANTELOPE BITTERBRUSH / BLUEBUNCH WHEATGRASS
ARTTST (*Artemisia tridentata* subsp. *tridentata)*	ANY	SRM 401 - BASIN BIGBRUSH
ARTTSV (*Artemisia tridentata* subsp. *vaseyana)*	ANY	SRM 402 - MOUNTAIN BIG SAGEBRUSH
ARTTSW (*Artemisia tridentata* subsp. *wyomingenis)*	ANY	SRM 403 - WYOMING BIG SAGEBRUSH
ARTARB (*Artemisia arbuscula)*	ANY	SRM 406 - LOW SAGEBRUSH

Table 5. Manual cover type assignments for the shrubland records.

EXISTING VEGETATION	ELEVATION RANGE	COVER TYPE ASSIGNMENT FOR THAT RECORD
PURTRI *(Purshia tridentata)*	< 6,000 FT.	SRM 104 - ANTELOPE BITTERBRUSH / BLUEBUNCH WHEATGRASS
ADEFAS *(Adenostoma fasciculatum)* or ERIFAS (*Eriogonum fasciculatum)* or QUEDUM (*Quercus dumosa)* or any *Arctostaphylos* spp.)	ANY	SRM 206 - CHAMISE CHAPARRAL
ANY *Ceanothus* spp.	ANY	SRM 208 - CEANOTHUS MIXED CHAPARRAL
ARTTST (*Artemisia tridentata* subsp. *tridentata)*	ANY	SRM 401 - BASIN BIGBRUSH
ARTTSV (*Artemisia tridentata* subsp. *vaseyana)*	ANY	SRM 402 - MOUNTAIN BIG SAGEBRUSH
ARTTSW (*Artemisia tridentata* subsp. *wyomingenis)*	ANY	SRM 403 - WYOMING BIG SAGEBRUSH
ARTARB (*Artemisia arbuscula)*	ANY	SRM 406 - LOW SAGEBRUSH
PURVIR *(Prunus virginiana)* or AMEALN (*Amelanchier alnifolia)* or SYMALB (*Symphoricarpos alba*) or any *ROSA* spp. (at least 2 of the above in combination)	ANY	SRM 421 - CHOKECHERRY / SERVICEBERRY / ROSE

Some cover types did not have enough records for analysis in the Region One data set because these cover types are not prevalent in that region. Many records were also deemed unusable and were not considered for division into cover types. Cover types SRM 103 -GREEN FESCUE, SRM 104 - ANTELOPE BITTERBRUSH / BLUEBUNCH WHEATGRASS, SRM 206 - CHAMISE CHAPARRAL, SRM 208 - CEANOTHUS MIXED CHAPARRAL, SRM 401 - BASIN BIGBRUSH, SRM 403 - WYOMING BIG SAGEBRUSH, SRM 406 - LOW SAGEBRUSH, SRM 414 - SALT DESERT SHRUB and SRM 614 - CRESTED WHEATGRASS had to be dropped due to lack of records (less than 50). The remaining cover types were SRM 101 - BLUEBUNCH WHEATGRASS, SRM 304 - IDAHO FESCUE / BLUEBUNCH WHEATGRASS, SRM 306 - IDAHO FESCUE / SLENDER WHEATGRASS, SRM 312 - ROUGH FESCUE / IDAHO FESCUE (added to the analysis), SRM 607 - WHEATGRASS / NEEDLEGRASS, SRM 402 - MOUNTAIN BIG SAGEBRUSH and SRM 421 - CHOKECHERRY / SERVICEBERRY / ROSE.

Assignment of Records to Structural Stage.

Once records were assigned to an SRM Cover type each record was assigned to a structural stage or class, within the appropriate cover type. The initial set of structural classes for the macro-scale had two classes that labeled a record as "Open Herbland" if that record had herbaceous cover $\leq$ 67% and "Closed Herbland" if the record (or plot) had > 67% herbaceous cover. Again using Fox-Pro commands, I set the STAG field to 1 (open herbland) where the GRAM (graminoid cover) plus FORB (forb cover) were $\leq$ 67. The remaining records were then set to 2 (closed herbland).

Discriminate analysis indicated that this initial classification provided unreliable results. Only 68% classification accuracy could be obtained; thus it was evident that the stages should be re-initialized. One of the rules in using discriminate analysis is that one can not assign a record to a class with a set of variables and then analyze this assignment using these same variables. Keeping this in mind and assuming that graminoid and forb cover would be important in the analysis procedures, a literature review on the SRM 101 - Bluebunch Wheatgrass cover type was used to establish new criteria for initial delineation of this cover type into structural classes.

Criteria for SRM 101 - Bluebunch Wheatgrass cover type were developed using information contained in the SRM cover type book (Society for Range Management, 1994), an eastern Oregon and western Idaho cover type book (Johnson and Simon, 1987), and a western Montana cover type book (Mueggler and Stewart, 1980). By averaging the BGRC (bare ground cover), ROCC (rock cover), GRAC (gravel cover) and LDC (liter cover) from stand averages of plots in the above literature, I devised a system for dividing records into structural classes. Tisdale (1994) stated that average cover values for the SRM 101 cover type were those found in a relatively open stand. All records were then placed in class 1 (Open Herbland, see Appendix B) when (LDC + ROCC + GRAC + BGRC) was $\geq$ 80 (the average value calculated from above). The remaining records were placed in structural class 2 (Closed Herbland).

The procedure developed for the SRM 101 Bluebunch Wheatgrass cover type was followed for SRM 304 - Idaho Fescue / Bluebunch Wheatgrass, SRM 306 - Idaho Fescue / Slender Wheatgrass, SRM 312 - Rough Fescue / Idaho Fescue and SRM 607 - Wheatgrass / Needlegrass cover types. Literature revealed calculated values near 80 (BGRC + GRAC + ROCC + LDC) for the cut-off between open and closed stands for each of these types and for simplicity reasons the value was rounded to 80.

For the SRM 402 cover type I used ecodata variables ROCC, BGRC, and GRAC. I did not use LDC values for initialization of stages in shrubland cover types, feeling it was less important than in herblands and could be saved for use in the analysis. I also queried on the SCOVT (tall shrub cover) field to see if any records had more than 10% cover of tall shrubs. Since none had greater than 10%, I could assume that only stage 3 (open low-medium shrub) and stage 4 (closed low-medium shrub) would be assigned. Literature review revealed that where (ROCC + BGRC + GRAC) was $\geq$ 40% cover the stand was relatively open. On this basis I assigned records to stages 3 and 4 using 40 as the cut-off value between open and closed low-medium shrublands.

A review of the SRM 421 data revealed several structural stages were possible: stage 3 (Open Low-Medium Shrubland), stage 4 (Closed Low-Medium Shrubland), stage 5 (Open Tall Shrubland),stage 6 (Closed Tall Shrubland, Single Stratum), and stage 7 (Closed Tall Shrubland, Multi-strata). To differentiate between the Low-Medium shrub records and the Tall shrub records I separated out those records having more tall shrub cover (SCOVT) than low (SCOVL) or medium (SCOVM) shrub cover. Using records that were dominated by low or medium shrub cover, I queried total shrub cover for that plot (SCOVTOT). If total shrub cover was < 67%, the record was initialized as stage 3 (Open Low-Medium Shrubland). If the total shrub cover for that record $\geq$ 67% the record was initialized as stage 4 (Closed Low-Medium Shrubland).

For the remaining records that were tall-shrub dominated, I used a total shrub cover (SCOVTOT) cut-off value of < 67% to place records into stage 5 (Open Tall Shrubland). With the remaining records that were considered closed tall shrublands, it was necessary to determine if one or more strata were present. I decided that where low or medium shrub cover was $\leq$ 10%, to include these did not merit a stratum. Any record meeting this criterion was initialized as stage 6 (Closed Tall Shrubland, Single Stratum). Remaining records would have a significant (> 10%) component of low-medium shrubs and would be initialized as stage 7 (Closed Tall Shrubland, Multi-Strata).

Discriminate Analysis

After data sets were prepared and structural stages had been initialized, it was necessary to determine the accuracy of this initial classification. The goal was to see if discriminate analysis could develop a function for discriminating between groups (structural stages), using the initial classification and then repeating this classification on a different set of records. Data were divided into two groups for this purpose: a sample set and a validation set. The sample set was used to develop a discriminate function using the ecodata variables for those records. When performing discriminate analysis one can not include those variables used to initialize records into their groups. Thus, for the herbland types, ROCC, LDC, GRAC and BGRC could not be used to develop a discriminate function because they were used in initialization of stages.

Once the function was developed for the sample set, it was run on the validation set. The DISCRIM program allowed simultaneous use of this procedure. A field called WEIGHT was used to set which records would be the sample set and which would be the validation set. This field was initialized randomly, using Fox-Pro software to randomly assigned a 1 or 0 to the weight column. The SYSTAT program was then used to develop functions using records with a WEIGHT of 1 and to validate the classification ability of these functions with records having a WEIGHT of 0. This process yielded the best set of variables for formation of the most accurate function (computer structural stage assignments versus my initial assignments). New combinations of variables and different cover types were addressed to eliminate as many dependant variables as possible for simplicity in using the function in later management strategies.

The list of dependant variables was also narrowed after consideration of canonical coefficients to see which variables were not contributing much to the formation of the discriminate function. Variables were eliminated one by one, making sure that probabilities of the multivariate test statistics stayed under 0.05 (a value I decided on for this study) and that the value of the canonical correlations did not decrease drastically. Highly correlated variables making basically the same contribution to the discriminate function were eliminated from further analysis.

Meso-scale The same cover type definitions applied to all scales used (macro- , meso-, and micro-scale) and no additional criteria were used in determining placement of records into cover types at the meso-scale. Two structural classes were added to the classification system (See Appendix C) : 1) a Closed / Mixed Herbland and, 2) an Open Low-Medium Shrub / Mixed Understory class (Appendix B) at the meso-scale. These classes resulted from splitting the Closed Herbland macro-scale class into two new stages and the Open Low-Medium Shrubland macro-scale class into two new classes.

With the addition of these stages, new criteria were developed to place records into appropriate structural stages. Using information from Mueggler and Stewart (1980), the SRM cover type book (Society for Range Management, 1994) and Johnson and Simon (1987), forb composition from what was considered "late seral" or "near climax" plots were used to distinguish between the Closed Mixed Herbland and Closed Stable Herbland stages. The general assumption of this method was that as forb cover decreased on a grass-dominated herbland, it was more stable or closer to a "late seral" stage and the structure of that area also changed.

Assignment of Records to Structural Stage.

Herbland Structural Stage Initiation. Open Herbland, Closed Mixed Herbland, and Closed Herbland were the three structural stages that were to be considered for the herbland cover types. Distinction between these classes used the criteria shown in Table 6.

Table 6. Herbland structural class assignments at the meso-scale.

SRM COVER TYPE	OPEN HERBLAND	CLOSED MIXED HERBLAND	CLOSED HERBLAND
SRM 101 - BLUEBUNCH WHEATGRASS	> 80% (BGRC + GRAC + LDC + ROCC)	≤ 80% (BGRC + GRAC + LDC + ROCC) AND FORB ≥ 15%	≤ 80% (BGRC + GRAC + LDC + ROCC) AND FORB < 15%
SRM 304 - IDAHO FESCUE / BLUEBUNCH WHEATGRASS	> 80% (BGRC + GRAC + LDC + ROCC)	≤ 80% (BGRC + GRAC + LDC + ROCC) AND FORB ≥ 25%	≤ 80% (BGRC + GRAC + LDC + ROCC) AND FORB < 25%
SRM 306 - IDAHO FESCUE / SLENDER WHEATGRASS	> 80% (BGRC + GRAC + LDC + ROCC)	≤ 80% (BGRC + GRAC + LDC + ROCC) AND FORB ≥ 30%	≤ 80% (BGRC + GRAC + LDC + ROCC) AND FORB < 30%
SRM 312 - ROUGH FESCUE / IDAHO FESCUE	> 80% (BGRC + GRAC + LDC + ROCC)	≤ 80% (BGRC + GRAC + LDC + ROCC) AND FORB ≥ 30%	≤ 80% (BGRC + GRAC + LDC + ROCC) AND FORB < 30%
SRM 607 - WHEATGRASS / NEEDLEGRASS	> 80% (BGRC + GRAC + LDC + ROCC)	≤ 80% (BGRC + GRAC + LDC + ROCC) AND FORB ≥ 10%	≤ 80% (BGRC + GRAC + LDC + ROCC) AND FORB < 10%

Definitions:

BGRC- Bare ground cover (see Appendix A)
GRAC- Gravel cover (see Appendix A)
ROCC- Rock cover (see Appendix A)
LDC- Litter/Duff cover (see Appendix A)
FORB- Forb cover (see Appendix A)

Distinction between classes was based on a review of Mueggler and Stewart (1980), Society for Range Management (1994) and Johnson and Simon (1989). Forb values between mid- and late-seral stages from the literature were obtained for each cover type and used as the cut-off between the Closed Mixed Herbland and Closed Herbland classes for these cover types.

Shrubland Structural Stage Initiation. Open Low-Medium Understory Shrubland, Open Low-Medium Mixed Understory Shrubland and Closed Low-Medium Shrubland were the three structural stages to be considered within the SRM 402 - Mountain Big Sagebrush cover type.

Open Low-Medium Mixed Understory Shrubland (class 5), Closed Low-Medium Shrubland (class 6), Open Tall Shrub (class 7), Closed Tall Shrub Single Stratum (class 8), and Closed Tall Shrub Multi-Strata (class 9) were to be considered for use within the SRM 421 (Chokecherry / Serviceberry / Rose) cover type. Any record in this cover type that had more tall shrub cover (SCOVT) than low or medium (SCOVL and SCOVM) would be considered in a tall shrub cover class. Any record not meeting these criteria was considered in a low-medium shrub class. A summary of the criteria used to initialize the shrubland stages can be found in Table 7.

Table 7. Shrubland structural class assignments at the meso-scale.

STRUCTURAL CLASS	SRM 402 - MOUNTAIN BIG SAGEBRUSH CRITERIA	SRM 421 - CHOKECHERRY / SERVICEBERRY / ROSE CRITERIA
OPEN LOW-MEDIUM SHRUBLAND	≥ 40% (BGRC + GRAC+ ROCC) AND < 10% FORB COVER	NOT APPLICABLE
OPEN LOW-MEDIUM MIXED UNDERSTORY SHRUBLAND	≥ 40% (BGRC + GRAC+ ROCC) AND ≥ 10% FORB COVER	< 67% TOTAL SHRUB COVER AND NOT DOMINATED BY TALL SHRUB COVER*
CLOSED LOW-MEDIUM SHRUBLAND	< 40% (BGRC + GRAC+ ROCC)	≥ 67% TOTAL SHRUB COVER AND NOT DOMINATED BY TALL SHRUB COVER*
OPEN TALL SHRUBLAND	NOT APPLICABLE	< 67% TOTAL SHRUB COVER AND DOMINATED BY TALL SHRUB COVER*
CLOSED TALL SINGLE STRATUM SHRUBLAND	NOT APPLICABLE	≥ 67% TOTAL SHRUB COVER, DOMINATED BY TALL SHRUB COVER* AND ≤ 10% MEDIUM OR LOW SHRUB COVER**
CLOSED TALL MULTI-STRATUM SHRUBLAND	NOT APPLICABLE	≥ 67% TOTAL SHRUB COVER, DOMINATED BY TALL SHRUB COVER* AND > 10% MEDIUM OR LOW SHRUB COVER**

* Having more tall shrub cover than low added to medium shrub cover
** Having > 10% cover of low or medium shrubs merited another stratum

Discriminate Analysis Methods at the Meso-Scale. Discriminate analysis methods were the same for this scale as they were for the macro-scale, and batch files were altered to discriminate among more structural classes than at the macro-scale.

Chi-Square Tests on the Hypotheses.

After both macro-and meso-scale discriminate analyses were run, the results for each cover type classification were tested using a chi-square test. The general null hypotheses of these tests were that the predicted groupings or classes (classifications assigned by the discriminate function) were not statistically different than the observed groupings or classes (structural classification assigned by me).

Development of Classification Functions for Structural Class Assignment

After the most accurate classification had been obtained, I used the SYSTAT discriminate analysis results to construct classification functions. Construction of these functions made use of group classification constants and function coefficients generated by the discriminate analysis.

Development of Pathways Between Structural Stages

Pathways or transitions from one structural class to another were developed through a literature review for the meso- and micro-scales. The purpose of pathway development is to show directional change in structure for a cover type under different forms of vegetation disturbance. Disturbances were identified as follow: overgrazing, fire, lack of fire and type of management action such as removal and/or replacement of the existing vegetation (plowing, seeding, etc) or prescribed fire and grazing management actions. Interpretive pathway models were developed to provide managers with information for obtaining desired structural attributes on a given management area.

RESULTS AND DISCUSSION

Structural Classes

The sets of structural stages resulting from the literature review and other methods mentioned are displayed in Tables 8 thru 10 to show a brief summary of these newly developed classes. Assigning a plot to a class can be done by using classification functions described later in this paper. Brief definitions and descriptions are included. The description shows the reader how a plot was initialized into that particular class. Definitions of the ecodata variables (BGRC, etc.) can be found in Appendix A. The values for significant forb cover in the meso- and micro-scales can be found in Table 11. In my opinion, the classes should be applicable on rangelands in general of the same SRM cover types; however, due to the differences in ecology and disturbance regimes among rangelands, the pathway models are intended for only this study area. For example, at the macro-scale, a SRM Bluebunch Wheatgrass cover type can be classified as an Open Herbland or Closed Herbland structural class outside of the study area using the same criteria developed in this study. The transitions of this cover type from class to class may be different in an area with depending on its ecology and disturbance regimes.

Table 8. Macro-scale structural classes.

STRUCTURAL CLASS	DEFINITION	DESCRIPTION
OPEN HERBLAND 1	OPEN CANOPY OF HERBACEOUS VEGETATION	$\geq$ 80% (BGRC + ROCC + GRAC + LDC) COVER
CLOSED HERBLAND 2	CLOSED CANOPY OF HERBACEOUS VEGETATION	< 80% (BGRC + ROCC + GRAC + LDC) COVER
OPEN LOW-MEDIUM SHRUBLAND 3	DOMINATED BY AN OPEN CANOPY OF LOW AND/OR MEDIUM-SIZED SHRUBS	$\geq$ 40% (BGRC + ROCC + GRAC) AND DOMINATED BY LOW AND/OR MEDIUM-SIZED SHRUBS
CLOSED LOW-MEDIUM SHRUBLAND 4	DOMINATED BY A CLOSED CANOPY OF LOW AND/OR MEDIUM-SIZED SHRUBS	< 40% (BGRC + ROCC + GRAC) AND DOMINATED BY LOW AND/OR MEDIUM-SIZED SHRUBS
OPEN TALL SHRUBLAND 5	DOMINATED BY AN OPEN CANOPY OF TALL SHRUBS	A CANOPY OF TALL SHRUBS WITH < 67% TOTAL SHRUB COVER (SCOVTOT)
CLOSED TALL SINGLE STRATUM SHRUBLAND 6	DOMINATED BY A CLOSED CANOPY OF TALL SHRUBS	A CANOPY OF TALL SHRUBS WITH $\geq$ 67% SCOVTOT AND < 10% LOW OR MEDIUM SHRUB COVER
CLOSED TALL MULTI-STRATA SHRUBLAND 7	DOMINATED BY A CLOSED CANOPY OF TALL SHRUBS IN SEVERAL LAYERS	A CANOPY OF TALL SHRUBS WITH $\geq$ 67% SCOVTOT AND $\geq$ 10% LOW OR MEDIUM SHRUB COVER

Definitions: Low shrubs - $\leq$ 20 inches (50 cm) in height;
Medium shrubs - > 20 inches (50 cm) and < 6.5 feet (2 m) tall
Tall shrubs - > 6.5 feet (2 m) tall but < 16.5 feet (5 m) tall

Table 9. Meso-scale structural classes.

STRUCTURAL CLASS	DEFINITION	DESCRIPTION
OPEN HERBLAND 1	OPEN CANOPY OF HERBACEOUS VEGETATION	≥ 80% (BGRC + ROCC + GRAC + LDC) COVER
CLOSED MIXED HERBLAND 2	CLOSED CANOPY OF MIXED HERBACEOUS VEGETATION	< 80% (BGRC + ROCC + GRAC + LDC) COVER AND A SIGNIFICANT FORB COMPONENT*
CLOSED HERBLAND 3	CLOSED CANOPY OF HERBACEOUS VEGETATION	< 80% (BGRC + ROCC + GRAC + LDC) COVER AND AN IN SIGNIFICANT FORB COMPONENT*
OPEN LOW-MEDIUM UNDERSTORY SHRUBLAND 4	OPEN CANOPY OF LOW AND/ OR MEDIUM SIZED SHRUBS	≥ 40% (BGRC + ROCC + GRAC + LDC) COVER AND AN INSIGNIFICANT FORB COMPONENT*
OPEN LOW-MEDIUM MIXED UNDERSTORY SHRUBLAND 5	OPEN CANOPY OF LOW AND/ OR MEDIUM SIZED SHRUBS WITH A MIXED UNDERSTORY	≥ 40% (BGRC + ROCC + GRAC + LDC) COVER AND A SIGNIFICANT FORB COMPONENT*
CLOSED LOW-MEDIUM SHRUBLAND 6	CLOSED CANOPY OF LOW AND/ OR MEDIUM SIZED SHRUBS	< 40% (BGRC + ROCC + GRAC + LDC) COVER
OPEN TALL SHRUBLAND 7	DOMINATED BY AN OPEN CANOPY OF TALL SHRUBS	A CANOPY OF TALL SHRUBS WITH < 67% TOTAL SHRUB COVER (SCOVTOT)
CLOSED TALL SINGLE STRATUM SHRUBLAND 8	DOMINATED BY A CLOSED CANOPY OF TALL SHRUBS	A CANOPY OF TALL SHRUBS WITH ≥ 67% SCOVTOT AND < 10% LOW OR MEDIUM SHRUB COVER
CLOSED TALL MULTI-STRATA SHRUBLAND 9	DOMINATED BY A CLOSED CANOPY OF TALL SHRUBS IN SEVERAL LAYERS	A CANOPY OF TALL SHRUBS WITH ≥ 67% SCOVTOT AND ≥ 10% LOW OR MEDIUM SHRUB COVER

* SEE TABLE 11 FOR SIGNIFICANT FORB VALUES.

Table 10. Micro-scale structural classes

STRUCTURAL STAGE	DEFINITION	DESCRIPTION
OPEN HERBLAND 1	OPEN CANOPY OF HERBACEOUS VEGETATION	$\geq$ 80% (BGRC + ROCC + GRAC + LDC) COVER
CLOSED MIXED HERBLAND 2	CLOSED CANOPY OF MIXED HERBACEOUS VEGETATION	< 80% (BGRC + ROCC + GRAC + LDC) COVER AND A SIGNIFICANT FORB COMPONENT*
CLOSED HERBLAND 3	CLOSED CANOPY OF STABLE HERBACEOUS VEGETATION	< 80% (BGRC + ROCC + GRAC + LDC) COVER AND AN IN SIGNIFICANT FORB COMPONENT*
OPEN LOW SHRUBLAND 4	OPEN CANOPY OF LOW SIZED SHRUBS	$\geq$ 40% (BGRC + ROCC + GRAC + LDC) COVER AND AN INSIGNIFICANT FORB COMPONENT*
OPEN LOW MIXED UNDERSTORY SHRUBLAND 5	OPEN CANOPY OF LOW SIZED SHRUBS WITH A MIXED UNDERSTORY	$\geq$ 40% (BGRC + ROCC + GRAC + LDC) COVER AND A SIGNIFICANT FORB COMPONENT*
CLOSED LOW SHRUBLAND 6	CLOSED CANOPY OF LOW SIZED SHRUBS	< 40% (BGRC + ROCC + GRAC + LDC) COVER AND AN INSIGNIFICANT FORB COMPONENT*
CLOSED LOW MIXED UNDERSTORY SHRUBLAND 7	CLOSED CANOPY OF LOW SIZED SHRUBS WITH A MIXED UNDERSTORY	< 40% (BGRC + ROCC + GRAC + LDC) COVER AND A SIGNIFICANT FORB COMPONENT*
MIXED SHRUB MIXED HERBACEOUS SHRUBLAND 8	A CANOPY OF A COMBINATION OF LOW, MID AND/OR TALL SHRUBS WITH A MIXED UNDERSTORY	WHERE NO SHRUB (LOW, MID OR TALL) HAS MORE THAN 10% COVER AND A SIGNIFICANT FORB COMPONENT*
OPEN MID SHRUBLAND 9	OPEN CANOPY OF MID SIZED SHRUBS	$\geq$ 40% (BGRC + ROCC + GRAC + LDC) AND DOMINATED BY MID SHRUBS

Table 10. Continued..

CLOSED MID SHRUBLAND 10	DOMINATED BY A CLOSED CANOPY OF MID SIZED SHRUBS	< 40% (BGRC + ROCC + GRAC + LDC) AND DOMINATED BY MID SHRUBS .
OPEN TALL SHRUBLAND 11	DOMINATED BY AN OPEN CANOPY OF TALL SHRUBS	A CANOPY OF TALL SHRUBS WITH < 67% TOTAL SHRUB COVER (SCOVTOT)
CLOSED TALL SHRUBLAND 12	DOMINATED BY A CLOSED CANOPY OF TALL SHRUBS IN SEVERAL LAYERS	A CANOPY OF TALL SHRUBS WITH ≥ 67% SCOVTOT SHRUB COVER

*SEE TABLE 11 FOR SIGNIFICANT FORB VALUES.

Table 11. Significant forb values by cover type.

COVER TYPE	SIGNIFICANT FORB VALUE
SRM 101 - BLUEBUNCH WHEATGRASS	< 15% COVER
SRM 304 - IDAHO FESCUE / BLUEBUNCH WHEATGRASS	< 25% COVER
SRM 306 - IDAHO FESCUE / SLENDER WHEATGRASS	< 30% COVER
SRM 312 - ROUGH FESCUE / IDAHO FESCUE	< 30% COVER
SRM 402 - MOUNTAIN BIG SAGEBRUSH	< 10% COVER
SRM 607 - WHEATGRASS / NEEDLEGRASS	< 10% COVER

Classification Results

Desirable properties of any classification system are: 1) to obtain a low misclassification rate, 2) to have as few independent variables as possible (for simplicity of use) and, 3) to obtain a high canonical correlation and low probabilities on the multivariate test statistics associated with low Euclidian distances. Standards on these results are more or less left to the discretion of the user. Analysis generally showed that as independent variables were eliminated, the misclassification rates increased. The importance of "ease of use" of discriminate functions (i.e., fewer independent variables) must be balanced against the desire for high reliability. Low misclassification rates were high priority in this study.

Misclassification Rates.

Misclassification rates for each cover type are shown in Table 12 (macro-scale) and Table 13 (meso-scale). Misclassification rates ranged from 9% to 40%. As an example, the SRM 101 cover type had a misclassification rate of 24% through discriminate analysis. Thus, the classification functions yielded "correct" results for 76% of the cases.

Table 12. Misclassification rates by cover type for the macro-scale analysis. (Percentage values are rounded to the nearest whole number.)

SRM COVER TYPE	MISCLASSIFICATION RATE
BLUEBUNCH WHEATGRASS (101)	24%
IDAHO FESCUE / BLUEBUNCH WHEATGRASS (304)	4%
IDAHO FESCUE / SLENDER WHEATGRASS (306)	9%
ROUGH FESCUE / IDAHO FESCUE (312)	9%
MOUNTAIN BIG SAGEBRUSH (402)	9%
CHOKECHERRY / SERVICEBERRY / ROSE (421)	40%
WHEATGRASS / NEEDLEGRASS (607)	9%

Standards for misclassification rates are user determined. In this study, any misclassification rate > 30% was deemed unacceptable. The SRM 421 - Chokecherry / Serviceberry / Rose cover type yielded a 40% misclassification rate. This cover type has the presence of many understory and overstory species and, according to these results, this classification system at the macro-scale is not appropriate when addressing the cover type.

Meso-scale. The above analysis was rerun using the meso-scale classes with the same objectives and goals in mind. Results of the meso-scale analysis are presented in Table 13.

Meso-scale analysis shows that, in general, when switching from macro-scale to meso-scale classification, misclassification rates increase slightly. An exception to this statement is the SRM 101 cover type which had a lower misclassification rate for meso-scale (19%) than for the macro-scale (24%) classification. The SRM 421 cover type remained at a 40% misclassification rate and is still considered unacceptable under the standards of this study.

Table 13. Misclassification rates by cover type for the meso-scale analysis. (Percentage values are rounded to the nearest whole number.)

SRM COVER TYPE	MISCLASSIFICATION RATE
BLUEBUNCH WHEATGRASS (101)	19%
IDAHO FESCUE / BLUEBUNCH WHEATGRASS (304)	16%
IDAHO FESCUE / SLENDER WHEATGRASS (306)	19%
ROUGH FESCUE / IDAHO FESCUE (312)	15%
MOUNTAIN BIG SAGEBRUSH (402)	20%
CHOKECHERRY / SERVICEBERRY / ROSE (421)	40%
WHEATGRASS / NEEDLEGRASS (607)	14%

Independent Variable Combination Results.

Macro-scale. The list of independent variables for the final classification functions having the fewest independent variables and lowest misclassification rates are presented in Tables 14 and 15. These variables are used in classification functions that will be presented later in this section. The variable combinations are different for each cover type.

Combinations of independent variables were as few as 4 for the SRM 304 cover type and as many as 8 for the SRM 101 cover type. The 9 independent variables in SRM 421 did not meet the misclassification standards. This could mean that some cover types lend themselves better to this classification system. In other words, structural differences in the SRM 304 cover type may be "picked-up" easier (only 4 attributes needed) than in the SRM 101 cover type.

Meso-scale. Independent variable combinations were also obtained for the meso-scale analysis and are presented in Table 15.

Table 14. Independent variable combinations for the macro-scale analysis. (See Appendix A for explanation of ECODATA fields)

SRM COVER TYPE	INDEPENDENT VARIABLES
BLUEBUNCH WHEATGRASS (101)	AZIM, SLOPE, MLC, BVC, SCOVTOT, SCOVL, SCOVM, GRAM
IDAHO FESCUE / BLUEBUNCH WHEATGRASS (304)	MLC, BVC, SCOVTOT, SCOVM, GRAM
IDAHO FESCUE / SLENDER WHEATGRASS (306)	MLC, BVC, GRAM, FORB
ROUGH FESCUE / IDAHO FESCUE (312)	AZIM, MLC, BVC, SCOVL
MOUNTAIN BIG SAGEBRUSH (402)	LDC, MLC, BVC, SCOVL
CHOKECHERRY / SERVICEBERRY / ROSE (421)	ELEV, AZIM, SLOPE, GRAC, LDC, MLC, BVC, TCOVTOT, GRAM, FORB
WHEATGRASS / NEEDLEGRASS (607)	SLOPE, MLC, BVC, SCOVTOT, SCOVL, GRAM

Table 15. Independent variable combinations for the meso-scale analysis. (See Appendix A for explanation of ECODATA fields)

SRM COVER TYPE	INDEPENDENT VARIABLES
BLUEBUNCH WHEATGRASS (101)	ELEV, AZIM, MLC, BVC, SCOVTOT, SCOVM, GRAM
IDAHO FESCUE / BLUEBUNCH WHEATGRASS (304)	ELEV, MLC, BVC, SCOVTOT, SCOVM, GRAM
IDAHO FESCUE / SLENDER WHEATGRASS (306)	ELEV, AZIM, MLC, BVC, SCOVTOT, SCOVL, GRAM
ROUGH FESCUE / IDAHO FESCUE (312)	AZIM, MLC, BVC, SCOVTOT, SCOVL, GRAM
MOUNTAIN BIG SAGEBRUSH (402)	ELEV, AZIM, SLOPE, LDC, MLC, BVC, TCOVTOT, SCOVTOT, SCOVL, SCOVM
CHOKECHERRY / SERVICEBERRY / ROSE (421)	ELEV, AZIM, SLOPE, BGRC, LDC, MLC, BVC, GRAM, FORB
WHEATGRASS / NEEDLEGRASS (607)	ELEV, AZIM, SLOPE, MLC, BVC, TCOVTOT, SCOVTOT, SCOVM, GRAM

In general, the number of independent variables forming the best discriminate function increased with the exception of SRM 101 - Bluebunch Wheatgrass. It can be expected that when discriminating between 2 stages (macro-scale) one would need fewer independent variables than when discriminating between 3 stages (meso-scale). One of the objectives of this study was to see if key attributes in quantifying a structural stage designation changed over scale. These results have shown that they do indeed change over scale, most of the cover types used more variables at the meso-scale than at the macro-scale and used different combinations of variables.

Multivariate test results.

Macro-scale. Discriminate analysis produced several multivariate test statistics to show the significance of this variable combination on their ability to discriminate between the structural stages. The analysis included the Wilks' Lambda, Pillai Trace and Hotelling-Lawley Trace tests. A low probability value (set at 0.05 for this study) for each of these tests meant that the combination of variables used was statistically significant in discriminating between groups. For macro-scale analysis the SRM 101 - Bluebunch Wheatgrass, SRM 304 - Idaho Fescue / Bluebunch Wheatgrass, SRM 306 - Idaho Fescue / Slender Wheatgrass, SRM 312 - Rough , SRM 402 - Mountain Big Sagebrush, and SRM

607 - Wheatgrass / Needlegrass cover types all had probabilities of 0.00 for each of the three tests. The SRM 421 - Chokecherry / Serviceberry / Rose cover type had probabilities of 0.023 (Wilks' Lambda), 0.021 (Phillai Trace), and 0.025 (Hotelling-Lawley Trace). These probabilities meant that the combination of variables used was statistically significant in discriminating between groups but this cover type exceeded the misclassification tolerance.

Meso-scale. At the meso-scale the SRM 101 - Bluebunch Wheatgrass, SRM 306 - Idaho fescue / Slender Wheatgrass , SRM 312 - Rough Fescue / Bluebunch Wheatgrass , and SRM 402 - Mountain Big Sagebrush cover types all had probabilities of 0.00 for each of the three tests. The SRM 304 - Idaho Fescue / Bluebunch Wheatgrass cover type had a probability of 0.00 for both the Wilks' Lambda and Hotelling-Lawley Trace tests and a probability of 0.01 for the Phillai Trace test. All of the above tests signified that the combinations of variables used were statistically significant in discriminating between groups.

Chi-square test results.

Macro-scale. Chi-square tests were used to test the following hypothesis: the group of observed classification groups (structural class designations) were statistically the same as the predicted classification groups (structural stage designations using the discriminate function). In other words, rejecting the hypothesis would mean that the observed classification scheme was statistically different than that of the predicted scheme. Chi-square test results are presented in Table 16 for the macro-scale and Table 17 for the meso-scale. A Chi-square value of $\geq$ 0.1 was the criterion to fail to reject the above hypothesis, implying that there was no evidence that the observed distribution of stages was different from the predicted distribution of stages.

For all of the cover types, the Chi-square values failed to reject the hypothesis at the macro-scale based on the criterion of this study. This implies that there was no evidence that the observed distribution of stages was different from the predicted distribution of stages.

Meso-Scale. The same tests were performed at the meso-scale and are presented in Table 17. In all the cover types, I failed to reject the hypothesis, except for SRM 304 - Idaho Fescue / Bluebunch Wheatgrass. The Chi-square value of 0.088 rejects the hypothesis and implies that there is evidence that the observed distribution of stages was different from the predicted distribution of stages at the meso-scale. This may be attributed to the small data set for this cover type. This classification scheme is not recommended for this cover type at this scale. The other cover types do fit well into this system according to Chi-square results.

Table 16. Chi-square results for the macro-scale classifications.

SRM COVER TYPE	PEARSON CHI-SQUARE	LIKELIHOOD CHI-SQUARE
BLUEBUNCH WHEATGRASS (101)	.338	.338
IDAHO FESCUE / BLUEBUNCH WHEATGRASS (304)	.864	.864
IDAHO FESCUE / SLENDER WHEATGRASS (306)	.691	.690
ROUGH FESCUE / IDAHO FESCUE (312)	.482	.482
MOUNTAIN BIG SAGEBRUSH (402)	.727	.727
CHOKECHERRY / SERVICEBERRY / ROSE (421)	.732	.768
WHEATGRASS / NEEDLEGRASS (607)	.759	.758

Table 17. Chi-square results for the meso-scale classifications.

SRM COVER TYPE	PEARSON CHI-SQUARE	LIKELIHOOD CHI-SQUARE
BLUEBUNCH WHEATGRASS (101)	.905	.904
IDAHO FESCUE / BLUEBUNCH WHEATGRASS (304)	.184	.088
IDAHO FESCUE / SLENDER WHEATGRASS (306)	.264	.248
ROUGH FESCUE / IDAHO FESCUE (312)	.182	.170
MOUNTAIN BIG SAGEBRUSH (402)	.756	.756
CHOKECHERRY / SERVICEBERRY / ROSE (421)	.954	.951
WHEATGRASS / NEEDLEGRASS (607)	.444	.419

Canonical correlations.

Macro-scale. A way to judge the substantive utility of a discriminate function is by examining the canonical correlation. A value of zero represents no group separation, whereas a value of 1.0 (the maximum value) indicates perfect group separation. Therefore, the closer the cover type's canonical correlation is to 1.0 the more variance its discriminate function accounts for. Canonical correlations of 0.865 (SRM 101 - Bluebunch Wheatgrass), 0.830 (SRM 304 - Idaho Fescue / Bluebunch Wheatgrass), 0.717 (SRM 306 - Idaho Fescue / Slender Wheatgrass), 0.761 (SRM 312 - Rough Fescue / Idaho Fescue), 0.761 (SRM 402 - Mountain Big Sagebrush) and 0.776 (SRM 607 - Wheatgrass / Needlegrass) were obtained from the analysis. Since the discriminate function for the SRM 421 - Chokecherry / Serviceberry / Rose cover type exceeded the misclassification limit, thus showing its inadequacy in separating the groups, further analysis was not necessary. The biological implications of this is that maybe a structural component is missing from this analysis and needs to be addressed in a future study. All of the cover types had canonical correlations that implied that their respective discriminate functions accounted for a large portion of the variance between the two stages at the macro-scale.

Meso-scale. The canonical correlations for the meso-scale analysis are presented in Table 18.

Table 18. Canonical correlations for the meso-scale analysis.

SRM COVER TYPE	FIRST CANONICAL CORRELATION	SECOND CANONICAL CORRELATION
BLUEBUNCH WHEATGRASS (101)	.708	.559
IDAHO FESCUE / BLUEBUNCH WHEATGRASS (304)	.892	.440
IDAHO FESCUE / SLENDER WHEATGRASS (306)	.757	.282
ROUGH FESCUE / IDAHO FESCUE (312)	.810	.513
MOUNTAIN BIG SAGEBRUSH (402)	.790	.250
CHOKECHERRY / SERVICEBERRY / ROSE (421)	EXCEEDED MISCLASSIFICATION LIMIT - N. A.	EXCEEDED MISCLASSIFICATION LIMIT - N. A.
WHEATGRASS / NEEDLEGRASS (607)	.689	.538

Discriminate analysis procedures will always produce one less discriminate function than the groups present. This is done in order to produce the three classification functions (one for each stage) at the meso-scale.

In all of the above cover types, the first discriminate function accounted for a large amount of the variance and the remaining variance was used to develop the next discriminate function. A good "rule of thumb" is that the reliability of a function developed on a data set of 25 observations should have a canonical correlation of at least 0.4 (Zuuring, personal communication). This standard is used as the particular rule for this study for interpretating the canonical correlations. Thus, the above discriminate functions and their resulting classification function are deemed reliable.

<u>Classification functions.</u>

<u>Macro-scale.</u> The discriminate function is based on maximizing differences between groups. The discriminate function and classification functions are mathematically related and are both a product of discriminate analysis. One can expect that misclassification rates attributed to the discriminate function will be synonymous with those of the classification function. Classification functions are assembled by using the group classification variables and group classification coefficients which are presented in Table 19.

Table 19. Group classification variables and group classification coefficients for the macro-scale.

COVERTYPE AND CLASS	CLASSIFICATION FUNCTIONS
SRM 101 - BLUEBUNCH WHEATGRASS : CLASS 1	-18.574 + .095(AZIM) +.192(SLOPE) - .107(MLC) - .015(BVC) + 5.095(SCOVTOT) - 1.686(SCOVL) - 3.917(SCOVM) + .213(GRAM) + .137(FORB)
SRM 101 - BLUEBUNCH WHEATGRASS : CLASS 2	-32.788 + .093(AZIM) +.232(SLOPE) - .124(MLC) - .239(BVC) + 2.911(SCOVTOT) - .548(SCOVL) - 1.780(SCOVM) + .461(GRAM) + .360(FORB)
SRM 304 - IDAHO FESCUE/ BLUEBUNCH WHEATGRASS : CLASS 1	-5.829 + .145(MLC) + .170(BVC) +1.817(SCOVTOT) - 2.985(SCOVM) + .180(GRAM)
SRM 304 - IDAHO FESCUE/ BLUEBUNCH WHEATGRASS : CLASS 2	-19.115 + ..444(MLC) +.706(BVC) + 3.346(SCOVTOT) - 7.261(SCOVM) + .233(GRAM)
SRM 306 - IDAHO FESCUE / SLENDER WHEATGRASS : CLASS 1	-3.862 + .017(MLC) + .092(BVC) +.095(GRAM) + .070(FORB)
SRM 306 - IDAHO FESCUE / SLENDER WHEATGRASS : CLASS 2	-8.067 + .0171(MLC) + .332(BVC) + .112(GRAM) + .046(FORB)
SRM 312 - ROUGH FESCUE / IDAHO FESCUE : CLASS 1	-4.316 + .026(AZIM) - .038(MLC) + .221(BVC) +.845(SCOVL)
SRM 312 - ROUGH FESCUE / IDAHO FESCUE : CLASS 2	-9.852 + .022(AZIM) +.175(MLC) +.494(BVC) + 1.352(SCOVL)
SRM 402 - MOUNTAIN BIG SAGEBRUSH : CLASS 1	-7.892 + .246(LDC) + .197(MLC) + .333(BVC) +.159(SCOVL)
SRM 402 - MOUNTAIN BIG SAGEBRUSH : CLASS 2	-17.810 + .424(LDC) +.343(MLC) +.473(BVC) + .134(SCOVL)
SRM 607 - WHEATGRASS / NEEDLEGRASS : CLASS 1	-10.774 + .173(SLOPE) -.015(MLC) + .318(BVC) + .1.587(SCOVTOT) - .817(SCOVL) + .245(GRAM)
SRM 607 - WHEATGRASS / NEEDLEGRASS : CLASS 2	-14.462 - .155(SLOPE) +.314(MLC) +.748(BVC) + .403(SCOVTOT) + .254(SCOVL) + .180(GRAM)

Classification functions can be used by collecting the appropriate ECODATA fields above and substituting the values into the equations for the appropriate cover type. After scores have been added in both equations the equation that produces the highest score will correlate to which structural class that plot should be initialized. The scores from the equation can also indicate how close a plot in a certain stage is to another possible structural class. Scores that are very close between two classification equations could imply that the plot is nearing a transitional period between classes. Conversely, scores that are very different imply that the plot will remain in that structural class for some time depending on disturbance regimes.

Meso-scale classification functions. Assemblence of these classification functions used the same methods as the macro-scale and are presented in Appendix B.

Use of these classification functions for meso-scale classification will be synonymous with macro-scale. The SRM 421 - Chokecherry / Serviceberry / Rose classification functions (for both scales) are not presented because they will produce unacceptable misclassification rates.

Pathway Diagrams

Transition of a site from one structural class to another is dependant on which disturbance or lack of disturbance that site undergoes. The dynamics of a plant community consist of the flux of individuals through the landscape over time (McAuliffe, 1988). The pathway diagrams (Figures 2 - 7) illustrate which transitions will occur under certain disturbance regimes. As stated in the introduction of this paper, these pathways are developed with the state and transition approach in mind and the literature review at the beginning of this report. This is in conjunction with the goal of this study to "move" away from the traditional pathway models using potential vegetation. These concepts were presented in the introduction of this paper and do not need to be repeated at this time. Future studies may be needed to prove or disprove the validity of these predictive diagrams of structural change. Disturbances considered here are: overgrazing, wildfire, fire suppression, management actions (mechanical removal of the existing vegetation, prescribed fire and/or revegetation methods), and protection from overgrazing. Three sets of diagrams were developed, one for each scale using knowledge gained from a literature review of the cover types. The object of these diagrams are to present a summary of how an area can change in regards to its structure classification and the disturbance applied.

Pathway diagrams are presented in Figures 2 thru 7 and are followed by brief descriptions. These include the macro-, meso- and micro-scales.

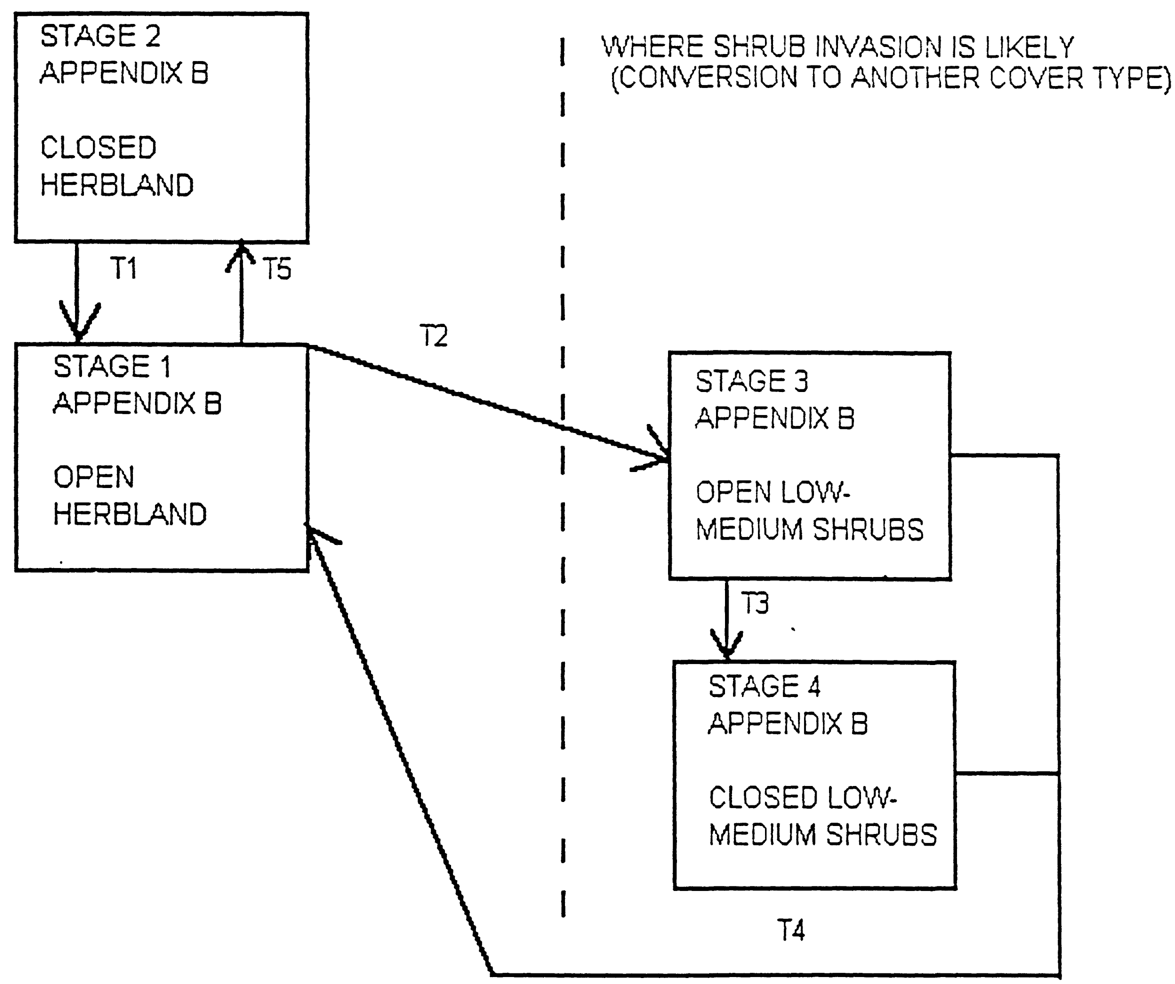


FIGURE 2. MACRO-SCALE GRASSLAND PATHWAY DIAGRAM.

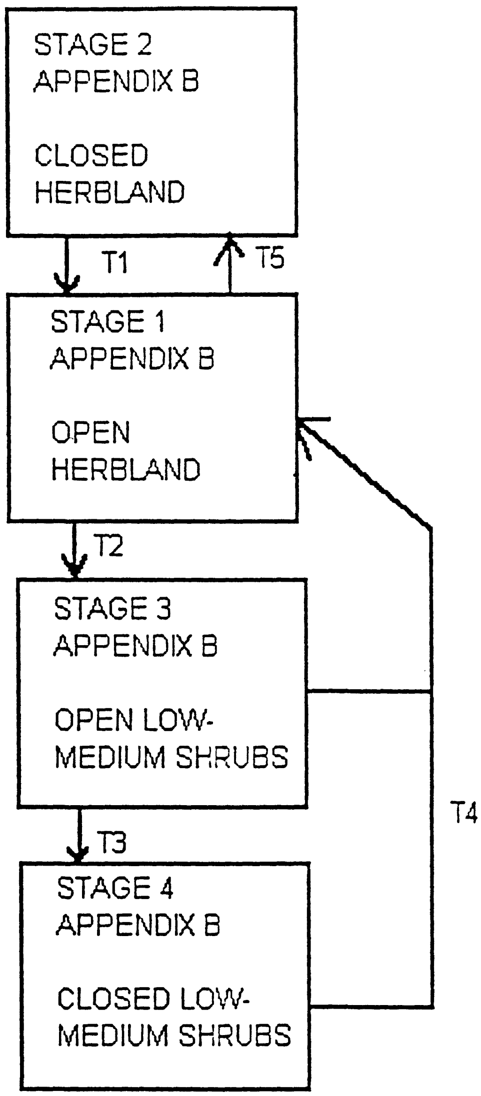


FIGURE 3. MACRO-SCALE PATHWAY DIAGRAM FOR SRM 402.

Transitions between structural classes for macro-scale grassland and SRM 402 - Mountain Big Sagebrush pathway diagrams are triggered by certain disturbances. The transitions are described with the knowledge gained from the literature review presented in the introduction. Transitions 1 and 2 (T1 and T2) are brought on by overgrazing and/or lack of fire (see Figure 2). Transition 3 (T3) is an inevitable transition with a continued lack of fire. Continued overgrazing will most likely "speed-up" this transition. Literature suggests that the only way to bring about transition 4 (T4) is by management actions (plowing, seeding, etc.) or by fire. Vallentine (1989) stated that in many areas of dense or closed shrub cover, management action is needed to bring about the reduction of the shrub cover and that changes in grazing policies are more or less ineffective on these areas. Transition 5 (T5) can be triggered by stopping overgrazing practices and allowing the cover of herbaceous species to increase.

Transitions 1, 2 and 3 would most likely be brought on by overgrazing and/or lack of fire for SRM 402 (see Figure 3). Once the shrub cover dominates, management actions would be needed to bring about transition 4. Stopping overgrazing practices would be necessary to trigger transition 5.

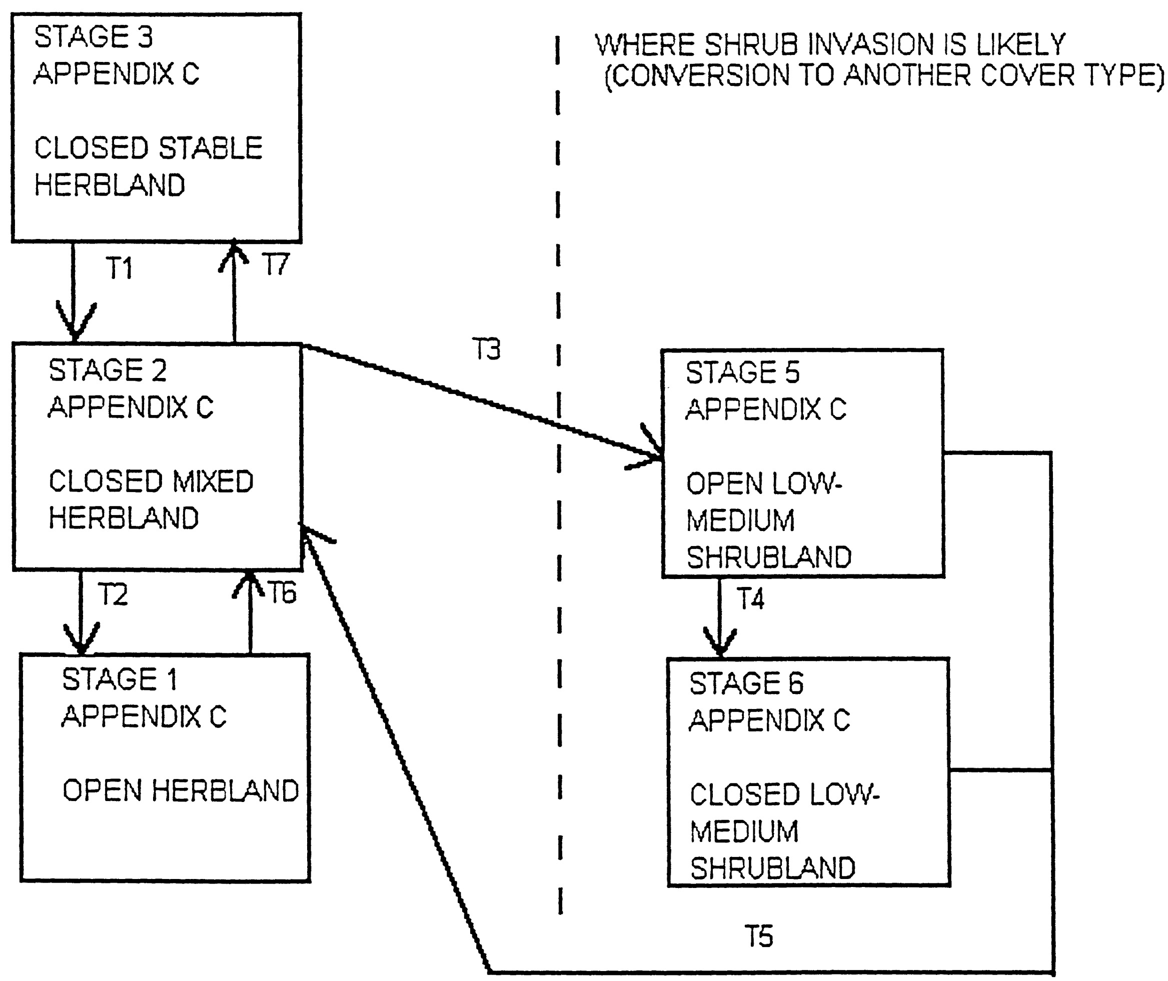


FIGURE 4. MESO-SCALE GRASSLAND PATHWAY DIAGRAM.

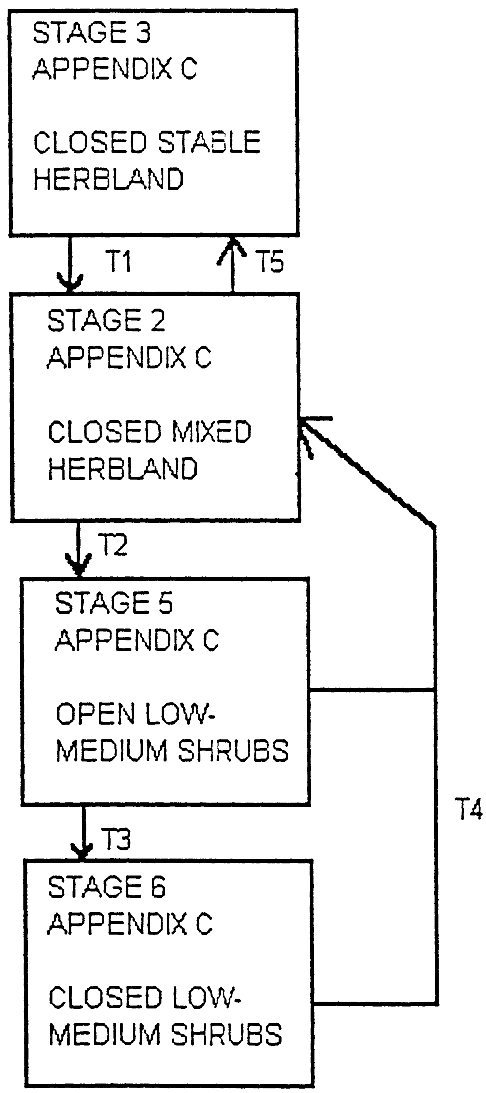


FIGURE 5. MESO-SCALE PATHWAY DIAGRAM FOR SRM 402.

In Figure 5 (the meso-scale grassland pathway), transitions 1, 2, 3 and 4 are brought on by overgrazing and/or lack of fire. The only way to bring about transition 5 is by management actions (plowing, seeding, etc.) or by fire. Transitions 6 and 7 can be triggered by stopping overgrazing practices and allowing the cover of herbaceous species to increase.

Transitions 1, 2 and 3 in the meso-scale pathway diagram for SRM 402 (Figure 6) would most likely be brought on by overgrazing and/or lack of fire. Once the shrub cover dominates, management actions would be needed to bring about transition 4. Stopping overgrazing practices would be necessary to trigger transition 5.

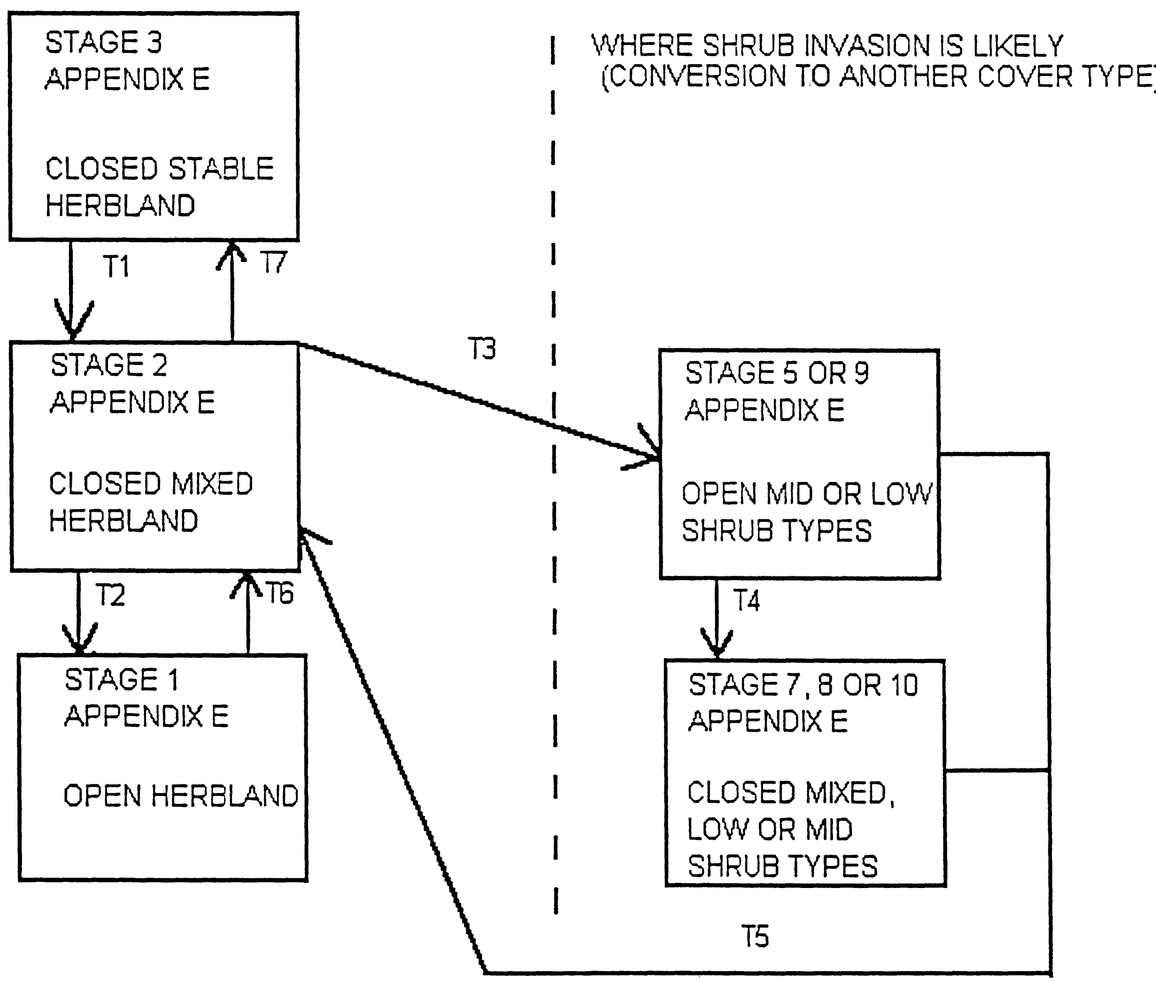


FIGURE 6. MICRO-SCALE GRASSLAND PATHWAY DIAGRAM.

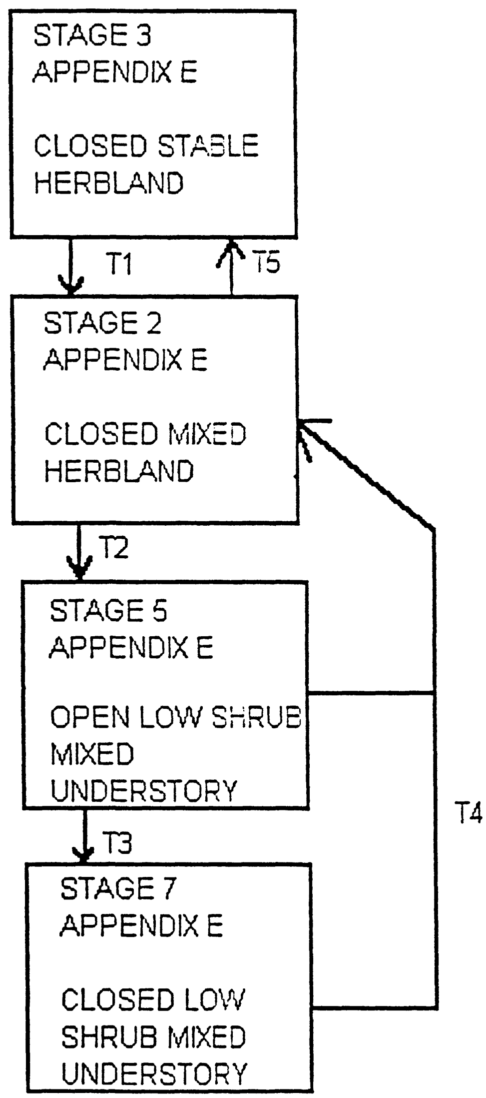


FIGURE 7. MICRO-SCALE PATHWAY DIAGRAM FOR SRM 402.

In Figure 7 (the micro-scale grassland pathway), transitions 1, 2, 3 and 4 are brought on by overgrazing and/or lack of fire. Literature suggests that the only way to bring about transition 5 is by management actions (plowing, seeding, etc.) or by fire. Transitions 6 and 7 can be triggered by stopping overgrazing practices and allowing the cover of herbaceous species to increase.

Transitions 1, 2 and 3 in the micro-scale pathway diagram for SRM 402 (Figure 8) would most likely be brought on by overgrazing and/or lack of fire. Once the shrub cover dominates, management actions would be needed to bring about transition 4. Stopping overgrazing practices would be necessary to trigger transition 5. As stated earlier these pathway models are presented as hypotheses and present the need for furher research. Future development of these pathways could be important as far as fire predictions and or management actions as the address oppuntunistic management (Laycock, 1990). Simulation models are a key tool for extrapolating current knowledge and relationships to new sites, with new combinations of driving variables and use as input to simulation models to represent regional patterns (Burke et al., 1987). By further developing these pathways through research one should be able to accomplish this goal of simulating regional patterns.

<u>Conclusions</u>

This study should be viewed as a developmental study that should and will be improved. Results are very encouraging considering this is a pioneering effort. It appears that this new classification system is slightly less accurate with shrub-dominated cover types than herbland cover types. This is most likely due to the large amount of structural variation present in a shrubland. An improved system is needed to quantify the SRM 421 - Chokecherry / Serviceberry / Rose cover type using structural attributes. Perhaps one of the limitations of this system is that it needs to have more structural stages to classify areas that have such a great diversity in structure.

The small number of records for the SRM 304 cover type at the meso-scale may have contributed to the failing Chi-square value. It was necessary to add another structural stage when converting from the macro-scale to the meso-scale. This further divided the number of records in this cover type among structural stages, allowing for only a small number of records in each group and perhaps contributing to the failed Chi-square value. This cover type at this scale should be reanalyzed with more records in the future to see if this assumption is true. The data analysis was frustrated by the lack of usable records in the data set. This research exposed a need for more consistent data collection techniques. Data collectors that left key fields blank made that record useless with this system. Highly reliable and complete data must be available for this system to work.

Another limitation confronted when developing this classification system is that I was restricted to only those structural attributes present in the Forest Service general form ecodata plots. Perhaps other structural attributes not addressed in this study would have increased the accuracy of the classification of the diverse shrubland type, SRM 421 - Chokecherry / Serviceberry / Rose. A strength of this classification system is its ability to accurately classify several SRM cover types using structural attributes found in the general form ecodata plots. One objective of this study was to develop this classification system, determine its accuracy, and produce a means by which it can be used. Using classification functions is a way in which this system can easily be used to assign plots to a structural class. The classification functions can also show a gradient of scores. Scores from a plot that are very similar between the classes, I feel, indicate a transitional area where opportunistic management can be used (Laycock, 1991). Other systems that use dichotomous keys do not show a gradient and do not provide this information.

Knowledge was gained from the analysis and literature review of these cover types and this system was under constant "evolution" during the study. Several things were learned during this process of trial and error. It is clear that each cover type should be addressed independently when assigning plots to a structural class. For example, the classification functions used in assigning a plot into a structural class differ between cover types and across scales. The user must place plots in a SRM cover type and determine the scale of the classification before in order to determine what classification functions are to be used.

Another goal of this study was to address existing vegetation and structure within the study area due to its disturbance/process driven nature. This study uses the SRM cover types which address the existing vegetation on a site and the structural components within it. The classes developed upon these criteria have the potential to be applied to other rangeland areas having the cover types involved in this study. The classification lends itself to an easy expansion using a hierarchial format into more defined scales. It is my recommendation that this system be viewed as applicable to broad scales with the potential for expansion in the future. The pathway models, however, may be somewhat site specific and depend on the ecology of a given area.

Vegetation structure and changes in structure on rangelands are very important as they affect wildlife, livestock and biological processes. Use of structure as a classification tool is an accurate way to predict the effects of certain management actions. The pathway models developed for this study address structure directly and incorporate disturbances as the driving forces in the transition between one structural class to another without implying directionality unlike other models based on climax or potential vegetation. Management on rangelands may be looked at differently using this type of model. An example is stated in Westoby et al. (1989) in regards to the "state-and-transition" model:

> "Management based on the range succession model has sought to determine a recommended carrying capacity which will be applied on a continuing basis. It has aimed to restrict stocking rate so as to avoid rangeland deterioration. The main management tool has thus been used with a defensive orientation. In contrast the state-and-transition formulation leads to policies which are opportunistic and oriented towards seeking positive improvement in the state of vegetation"

Management under this type of system would also be more flexible and less dependant on fixed policies. For example, this model like the state-and-transition model should influence managers to drop the assumption that conservative grazing is the safest policy. In some areas very heavy grazing or fire may be the most constructive thing to do (Westoby et al., 1989). Perhaps regulation should be focused on changes in the existing state of the land and not the potential for some "stable climax" community. I realize that some issues of "practicality" lie within using this system but the problems and possibilities of such a system merit exploration.

The simplistic nature of this classification system and its pathway models develop a need for further research. Once these classifications are in place there will be a need to validate the models developed here and to access rates and probabilities of transitions between structural classes. Such information will provide valuable input into further expanded models using existing vegetation and its structure (Calloway and Davis, 1993).

I feel that this system has the potential to be used in fire potential mapping. The structural stages could be tied into some fire potential value through further study and mapped. Wildlife managers should in the future, be able to map these structural stages across a landscape and predict movement corridors for certain wildlife species. This system is an asset in areas that have a high frequency of disturbance and may be more accurate in the prediction of vegetation change than potential vegetation classification systems. As with all classification systems, there is room for improvement and this system should lend itself to research in the future.

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APPENDIX A: ECODATA GENERAL FORM FIELDS

KEYID:* 15 character record identifier field containing information on the agency, region or state, national forest, ranger district, year, examiner and plot number of the record.

VEGFORM: 2 character field identifying the potential vegetation formation of the plot.

HABTYPS:* 6 character field of the understory indicator species which describes the potential vegetation classification of the plot.

HABTYPT:* An additional 6 character field of the understory indicator species which describes the potential vegetation classification of the plot.

HABTYPP:* An additional 6 character field of the understory indicator species which describes the potential vegetation classification of the plot.

CTDOMU:* 6 character field that describes the dominate species in the upper layer (above 6.5 ft. tall), of the plot.

CTCODU:* 6 character field that describes the codominate species in the upper layer (above 6.5 ft. tall), of the plot.

CTDOMM:* 6 character field that describes the dominate species in the middle layer (2.5 to 6.5 ft. tall), of the plot.

CTCODM:* 6 character field that describes the codominate species in the middle layer (2.5 to 6.5 ft. tall), of the plot.

CTDOML:* 6 character field that describes the dominate species in the lower layer (below 2.5 ft. tall), of the plot.

CTCODL:* 6 character field that describes the codominate species in the lower layer (below 2.5 ft. tall), of the plot.

ELEV:* Numeric (5) field containing the elevation of the plot above Mean Sea Level in feet.

APPENDIX A - continued

AZIM:* Numeric (3) field containing the declination-corrected azimuth of the plot's slope aspect to the nearest degree.

SLOPE:* Numeric (3) field containing the average percent slope of the terrain on which the sample plot is located.

BGRC:* Numeric (4) field indicating the bare soil cover at the plot's soil surface plane. (< 1/16 in. diameter soil particles)

GRAC:* Numeric (4) field indicating the gravel cover at the plot's soil surface plane. (1/16 to 3 in. diameter)

ROCC:* Numeric (4) field indicating the rock cover at the plot's soil surface plane. (> 3 in. diameter)

LDC:* Numeric (4) field indicating the litter, duff and ash cover at the plot's soil surface plane.

MLC:* Numeric (4) field indicating the moss, lichen, fungi and alga cover at the plot's soil surface plane.

BVC:* Numeric (4) field indicating the soil surface taken up by the live basal or root crown portion of vascular plants.

TCOVTOT:* Numeric (4) field that holds the percent canopy cover for trees as a life form for the total tree cover.

TCOVSEE: Numeric (4) field that holds the percent canopy cover for trees as a life form for the seedling (< 0.1 in. DBH) tree cover.

TCOVSAP: Numeric (4) field that holds the percent canopy cover for trees as a life form for the sapling (0.1 to 4.9 DBH) tree cover.

TCOVPOL: Numeric (4) field that holds the percent canopy cover for trees as a life form for the pole (5.0 to 8.9 DBH) tree cover.

APPENDIX A - continued

TCOVMED: Numeric (4) field that holds the percent canopy cover for trees as a life form for the medium (9.0 to 20.9 DBH) tree cover.

TCOVLAR: Numeric (4) field that holds the percent canopy cover for trees as a life form for the sapling (20.9 to 32.9 DBH) tree cover.

TCOVVLG: Numeric (4) field that holds the percent canopy cover for trees as a life form for the pole (> 32.9 DBH) tree cover.

SCOVTOT:* Numeric (4) field that holds the percent canopy cover for shrubs as a life form for the total shrub cover.

SCOVL:* Numeric (4) field that holds the percent canopy cover for shrubs as a life form for the low (< 2.5 ft. tall) shrub cover.

SCOVM:* Numeric (4) field that holds the percent canopy cover for shrubs as a life form for the medium (2.5 to 6.5 ft. tall) shrub cover.

SCOVT:* Numeric (4) field that holds the percent canopy cover for shrubs as a life form for the tall (> 6.5 ft. tall) shrub cover.

GRAM:* Numeric (4) field that holds the percent canopy cover for the graminoid cover.

FORB:* Numeric (4) field that holds the percent canopy cover for the forb cover.

* Indicates those fields that were used in the analysis.

APPENDIX B. CLASSIFICATION FUNCTIONS FOR THE MESO-SCALE

SRM COVER TYPE AND CLASS	CLASSIFICATION FUNCTIONS
SRM 101 - BLUEBUNCH WHEATGRASS: CLASS 1	-25.858 + .004(ELEV) +.090(AZIM) - .102(MLC) -.104(BVC) + 2.404(SCOVTOT) - 2.546(SCOVM) + .115(GRAM)
SRM 101 - BLUEBUNCH WHEATGRASS: CLASS 2	-29.947 + .005(ELEV) + .095(AZIM) + .110(MLC) +.067(BVC) + 1.931(SCOVTOT) - 1.755(SCOVM) + .054(GRAM)
SRM 101 - BLUEBUNCH WHEATGRASS: CLASS 3	-18.639 + .003(ELEV) + .082(AZIM) + .121(MLC) -.026(BVC) + 2.574(SCOVTOT) - 2.803(SCOVM) + .052(GRAM)
SRM 304 - IDAHO * FESCUE / BLUEBUNCH WHEATGRASS: CLASS 1	-13.963 + .003(ELEV) +.144(MLC) -.093(BVC) + 3.116(SCOVTOT) - 2.211(SCOVM) + .141(GRAM)
SRM 304 - IDAHO * FESCUE / BLUEBUNCH WHEATGRASS: CLASS 2	-25.329 + .003(ELEV) + .342(MLC) +.222(BVC) + 4.544(SCOVTOT) - 5.904(SCOVM) + .242(GRAM)
SRM 304 - IDAHO * FESCUE / BLUEBUNCH WHEATGRASS: CLASS 3	-27.703 + .003(ELEV) + 547(MLC) + .967(BVC) + 3.873(SCOVTOT) - 8.368(SCOVM) + 110(GRAM)
SRM 306 - IDAHO FESCUE / SLENDER WHEATGRASS: CLASS 1	-62.030 + .013(ELEV) + .022(AZIM) +.066(SLOPE) -.006(MLC) +.639(BVC) + 6.914(SCOVTOT) - 5.598(SCOVL) + .257(GRAM)
SRM 306 - IDAHO FESCUE / SLENDER WHEATGRASS: CLASS 2	-77.200 + .013(ELEV) + .028(AZIM) + .124(SLOPE) + .170(MLC) + 1.039(BVC) + 7.590(SCOVTOT) - 6.170(SCOVL) + .312(GRAM)
SRM 306 - IDAHO FESCUE / SLENDER WHEATGRASS: CLASS 3	-64.833 + .013(ELEV) + .024(AZIM) + .089(SLOPE) + .120(MLC) + .898(BVC) + 6.561(SCOVTOT) - 5.133(SCOVL) + .256(GRAM)
SRM 312 - ROUGH FESCUE / IDAHO FESCUE: CLASS 1	-12.561 + .032(AZIM) + .022(MLC) + .419(BVC) + 1.025(SCOVTOT) - .479(SCOVL) + .217(GRAM)
SRM 312 - ROUGH FESCUE / IDAHO FESCUE: CLASS 2	-28.774 + .035(AZIM) + .272(MLC) + 1.014(BVC) + .319(SCOVTOT) - .185(SCOVL) + .252(GRAM)

APPENDIX B. CONTINUED

SRM COVER TYPE AND CLASS	CLASSIFICATION FUNCTIONS
SRM 312 - ROUGH FESCUE / IDAHO FESCUE: CLASS 3	-14.747 + .027(AZIM) + .219(MLC) + .625(BVC) + .391(SCOVTOT) + 770(SCOVL) + .184(GRAM)
SRM 402 - MOUNTAIN BIG SAGEBRUSH: CLASS 1	-49.495 + .011 (ELEV) + .013(AZIM) + .092(SLOPE) + .144 (LDC) + .386(MLC) + .291(BVC) + 1.514(TCOVTOT) - .312(SCOVTOT) + .679(SCOVL) +.603(SCOVM)
SRM 402 - MOUNTAIN BIG SAGEBRUSH: CLASS 2	-52.118 + .011(ELEV) + .014(AZIM) + .068(SLOPE) + .165(LDC) + .342(MLC) + .274(BVC) + 1.219(TCOVTOT) - .348(SCOVTOT) + .718(SCOVL) + .632(SCOVM)
SRM 402 - MOUNTAIN BIG SAGEBRUSH: CLASS 3	-60.014 + .011(ELEV) + .014(AZIM) + .066(SLOPE) + .345(LDC) + .509(MLC) + .427(BVC) + 1.542(TCOVTOT) - .521(SCOVTOT) + .901(SCOVL) + .881(SCOVM)
SRM 607 - WHEATGRASS / NEEDLEGRASS: CLASS 1	-38.475 + .015 (ELEV) + .004(AZIM) + .275(SLOPE) - 176(MLC) + .195(BVC) - 60.274(TCOVTOT) + 1.225(SCOVTOT) + 2.150(SCOVM) + .552(GRAM)
SRM 607 - WHEATGRASS / NEEDLEGRASS: CLASS 2	-45.966 + .015 (ELEV) + .015(AZIM) + .377(SLOPE) - .049(MLC) + .136(BVC) - 36.206(TCOVTOT) + 1.225(SCOVTOT) + 1.075(SCOVM) + .591(GRAM)
SRM 607 - WHEATGRASS / NEEDLEGRASS: CLASS 3	-55.786 + .017(ELEV) - .000(AZIM) + .255(SLOPE) - .221(MLC) + .233(BVC) - 66.405(TCOVTOT) + 1.052(SCOVTOT) + 2.638(SCOVM) + .744(GRAM)

*The SRM 304 cover type at this scale failed the Chi-square test and may produce a distribution of predicted stages that is different from the distribution of the observed stages even though classification rates will be acceptable.